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GEOGRAPHIC INFORMATION SYSTEMS IN
HIGH SCHOOL GEOGRAPHY EDUCATION:
A FEASIBILITY STUDY

by

C. Sonia Wardley

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Geography

Western Michigan University
Kalamazoo, Michigan
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GEOGRAPHIC INFORMATION SYSTEMS IN
HIGH SCHOOL GEOGRAPHY EDUCATION:
A FEASIBILITY STUDY

C. Sonia Wardley, M.A.

Western Michigan University, 1997

This research focused on three aspects of the integration of GIS into the high school curriculum. Firstly, the investigation strove to demonstrate how GIS could enrich the high school geography curriculum in Michigan. Secondly, GIS software programs were evaluated for suitability using three techniques, and thirdly, the study area high schools were assessed for their technological capabilities relative to GIS.

The pedagogical and cognitive benefits of using GIS as a tool were established from the pertinent literature and the feasibility of incorporating GIS into the curriculum was examined with the reference to the Michigan geography content standards and benchmarks. Four GIS software programs, chosen on the basis of selected criteria, were systematically analyzed for ease-of-use. This was followed by a nine criteria evaluation conducted by high school students. The technological status of high schools within the study area, established through questionnaires, was related to environmental and enrollment data and to the hardware requirements of the selected GIS programs.

Generic GIS projects were successful aligned within the context of the Michigan curriculum framework. The evaluations revealed that of the selected GIS programs, Map Factory was easiest to use. However, the students favored ArcView and MapInfo. There was some evidence that age and gender influenced student preferences. The study area high schools were on the whole technically ill-equipped to implement GIS and many did not provided computer access to social studies classes.

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C. Sonia Wardley

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CHAPTER I

INTRODUCTION

Background

The academic discipline of geography has been neglected in American schools for over 50 years (Natoli, 1986). In 1982 only 16% of high school graduates had completed a course in geography. Over the next five years this figure continued to drop, before increasing to 21% by 1990. This was less than half of the percentage of students completing history courses (Figure 1) (U.S. National Education Goals Panel, 1993).

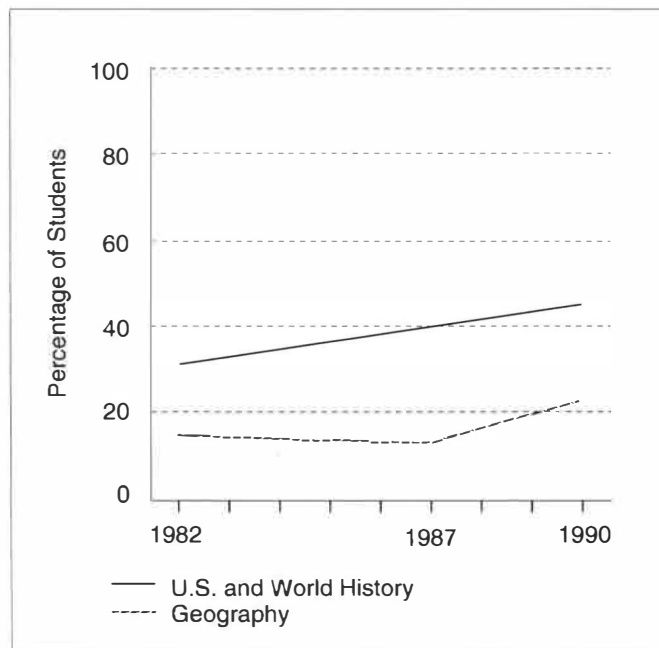


Figure 1. High School Course Completion—History and Geography.

Source: U.S. National Education Goals Panel. The National Education Goals Report: Building a Nation of Learners: The National Report. Vol. 1. Washington, D.C.: GPO, 1993.

Americans are beginning to realize, as communication networks increasingly encircle the globe, they can no longer remain ignorant of the world around them if they are to compete successfully in a world economy. So believed the Nation's governors and President Bush, when in 1990 they adopted six National Education Goals to be achieved by the year 2000 (Figure 2). Within Goal 3, geography was established as one of five core subjects, along with English, mathematics, science, and history. The objective was to establish core disciplines "in which all U.S. students are expected to demonstrate competency in challenging subject matter by the year 2000" (Goal 3, U.S. National Education Goals Panel, 1993) (Figure 2). Committees were subsequently established to guide the implementation of these goals, including the National Assessment of Educational Progress (NAEP): Geography Consensus Project (U.S. Department of Education, 1994). The NAEP developed a blueprint for a national assessment in geography, which it was authorized by Congress to administer every five years beginning in 1994. The results of the first national assessment in geography showed only approximately one quarter of 4th, 8th, and 12th graders met the performance standard in geography (Figure 3) (National Center for Educational Statistics, 1995). As this assessment was administered almost half way through the ten year time frame of Goals 2000: Educate America Act of 1994 (Public Law 103-227), there is still a long way to go to reach Goal 3 as established by the nation's governors. Nineteen ninety-four was also marked by the publication of Geography for Life: National Geography Standards (Geography Education Standards Project, 1994). This document details eighteen standards on geography content matter, skills, and perspectives which "the geographical informed person" should know and be able to do. The standards were presented as guidelines for state and local school districts to adapt to regional requirements.

THE NATIONAL EDUCATION GOALS

Goal 1: By the year 2000, all children in America will start school ready to learn.

Goal 2: By the year 2000, the high school graduation rate will increase to at least 90 percent.

Goal 3: *By the year 2000, American students will leave grades four, eight, and twelve having demonstrated competency in challenging subject matter, including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so that they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.*

Goal 4: By the year 2000, U.S. students will be first in the world in science and mathematics achievement.

Goal 5: By the year 2000, every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.

Goal 6: By the year 2000, every school in America will be free of drugs and violence and will offer a disciplined environment conducive to learning.

Figure 2. The National Education Goals. (This author's emphasis)

Source: U.S. National Education Goals Panel. The National Education Goals Report: Building a Nation of Learners: The National Report. Vol. 1. Washington, D.C. GPO, 1993.

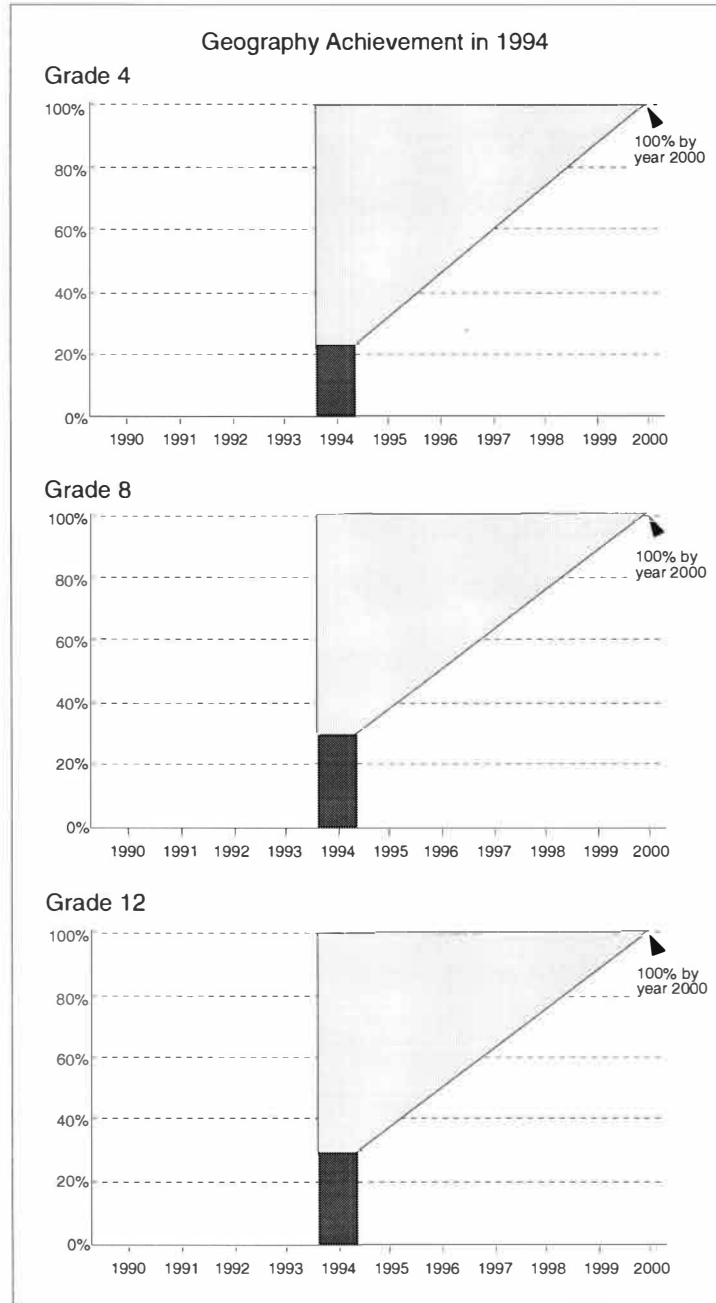


Figure 3. Percentage of Students Who Met the Goals Panel's Performance Standard in Geography and the Projected Improvement for 100% Compliance by 2000.

Source: U.S. National Education Goals Panel. The National Education Goals Report: Building a Nation of Learners. Washington, D.C. GPO, 1995.

All this activity on the national front, prompted many state educators to begin work drafting state content standards in geography. For example, in Michigan the development of the Michigan Framework for Social Studies Education: Content Standards (Michigan Department of Education, 1995) occurred concurrently with the period of National Standards' development. Therefore, the Michigan content standards in geography, although similar, do not represent a direct adaptation of the National Standards. Both the National and the Michigan standards are based on the Five Fundamental Themes of Geography, which were developed in 1984 and published in Guidelines for Geographic Education: Elementary and Secondary Schools (Joint Committee on Geographic Education, 1984). The Michigan Framework for Social Studies Education was implemented state-wide in 1996. Student performance in geography will be assessed, along with other social studies subjects, by the Michigan Educational Assessment Program (MEAP) in grades 5 and 8, and by the High School Proficiency Test in grade 11, beginning in 1999. The State's adoption of content standards will necessitate major reforms in geography education in Michigan. Hence, there is an immediate necessity to provide teachers in Michigan with new programs, materials, and tools with which they can teach geographical concepts and content effectively and efficiently, so their students can meet these new standards.

The NAEP Geography Consensus Project details the tools required to study geography. These include maps, globes, three-dimensional models, aerial photographs, satellite images, and geographic information systems (GIS) (U.S. Department of Education 1994). Similarly, Geography for Life: National Geography Standards describes the use of tools and technologies such as geographic information systems in geographic inquiry as essential skills students are expected to learn in order to analyze spatial patterns (Geography Education Standards Project, 1994). While the geographic information system is becoming increasingly important in government,

industry, business, and tertiary educational institutions for the manipulation of spatial data, it has not yet gained widespread acceptance in pre-collegiate education. *Can GIS be successfully integrated into K–12 geography education?* This question is the major focus of this research.

Research Problem

The research question encompasses numerous cognitive, pedagogical, curriculum, and software considerations, which suggest a number of subsidiary questions, such as: Where in the geography curriculum could GIS be effectively utilized? Would a GIS facilitate better understanding of geographical concepts and content than traditional teaching methods? Are there commercial or educational GIS software packages suitable for use in K–12 education? Do schools have the necessary hardware to run GIS programs? Not all these questions could be addressed in this research. Consequently, it was decided to narrow the investigation by targeting three aspects of GIS implementation in K–12 education. These were:

1. How could GIS be incorporated into the curriculum? Since there is no national curriculum in the United States, nor do many states have prescribed curricula, the curriculum is most frequently determined at an intermediate or school district level (Stoltman and Wardley, 1996). In order to achieve some degree of widespread applicability, this research studied the content standards and benchmarks upon which individual curricula are developed. Although the National Content Standards in Geography were published in 1994 (Geography Education Standards Project, 1994), these are frequently not adopted directly at a state level, but modified to reflect local educational requirements (Stoltman and Wardley, 1996). This results in geography content standards varying from state to state; hence a single state, Michigan, was chosen for this analysis. This project concentrated on identifying those unique GIS

features which could enable students to more effectively achieve the benchmarks of the Michigan Framework for Social Studies Education: Content Standards (Michigan Department of Education, 1995).

2. Which GIS software program is most suitable for schools? At this time there are no GIS specifically designed for K–12 education. Teachers who have embraced this technology have to select software from a wide array of higher educational and business programs, none of which have been developed with the school-aged student user in mind. This research, therefore, selected a number of commercial GIS for a review of their suitability for use in schools. Having established which spatial analysis techniques are most applicable to teaching the Michigan content standards, the software programs were examined for their ease of use, both in a systematic analysis and in a subjective evaluation by students. The purchase costs and hardware requirements of the programs were also taken into account.

3. Are schools technologically equipped to implement GIS? The technology is complex, expensive, and requires high powered computer hardware. This raises the question of whether schools have the necessary computers to run GIS programs. Further, the function of a classroom-based GIS will not be the same at all levels of K–12 education because of the different cognitive developmental and pedagogical requirements of students at various grade levels. GIS are complex computer programs, which are not known for their user friendliness (Medyckyj-Scott, 1991). It is probable that among K–12 students, those in grades 9 through 12 would make the maximum use of a school-based GIS. Consequently, this project was limited to the potential role of GIS in high schools. It was further determined to ascertain the technological status of a number of Michigan high schools. This investigation was restricted to high schools in the cities of Battle Creek and Kalamazoo and the surrounding rural areas. The study area, shown in Figure 4, was chosen to provide a variety of urban, suburban, and rural

schools with student populations ranging from approximately 200 to 1,300 pupils.

The research question was thus more narrowly focused to state:

Could GIS be successfully integrated into high school geography education in a selected region of southwest Michigan?

The research design for the investigation of this problem is summarized in Figure 5. The methodologies for each of the three sections outlined above are discussed in subsequent chapters. The proposed outcomes of the research will be a recommendation of a software program suitable for use in high school geography education in a selected region of southwest Michigan and the potential role of GIS in these classrooms.

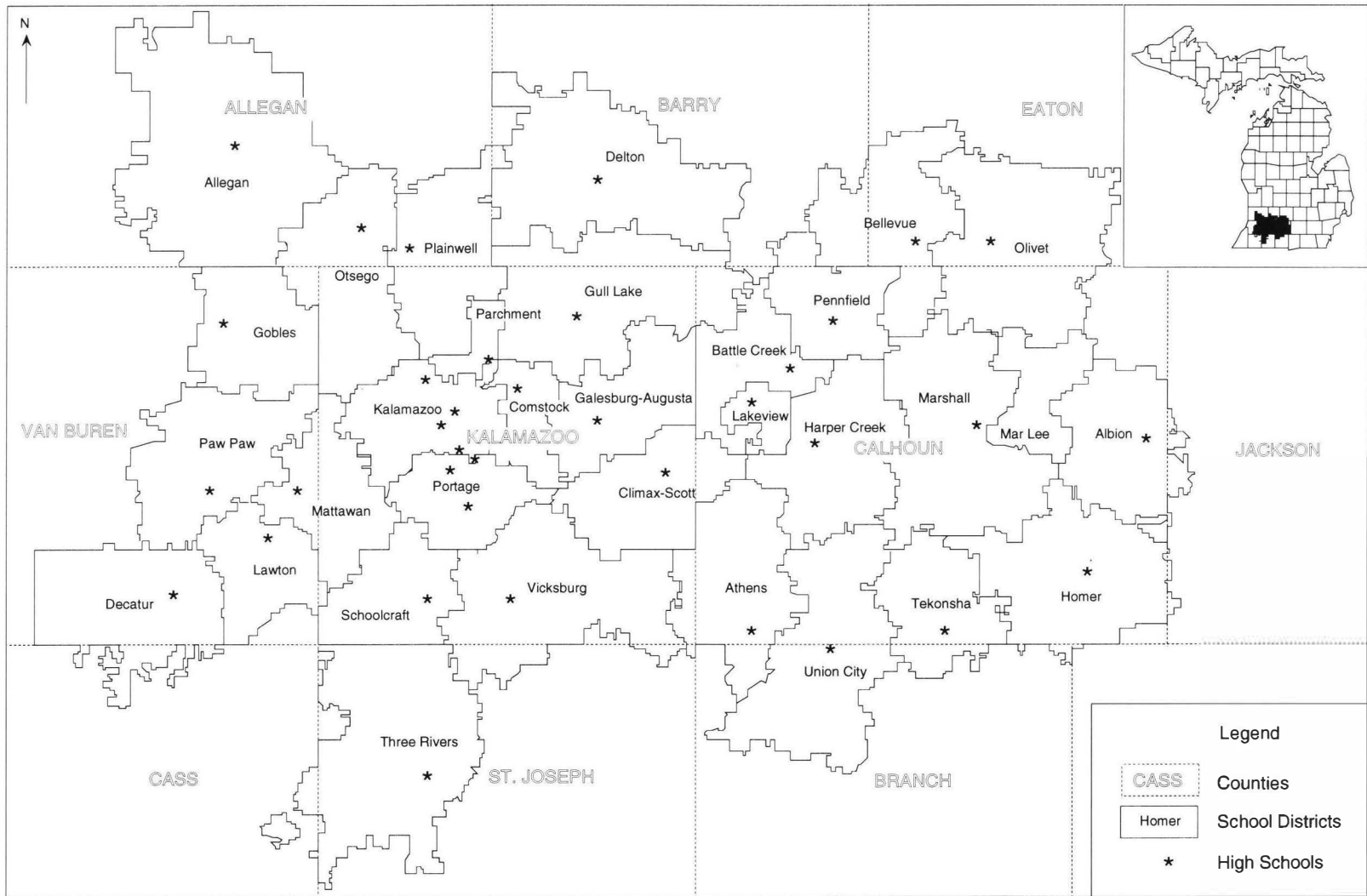


Figure 4. The Study Area Showing the School Districts and High Schools.

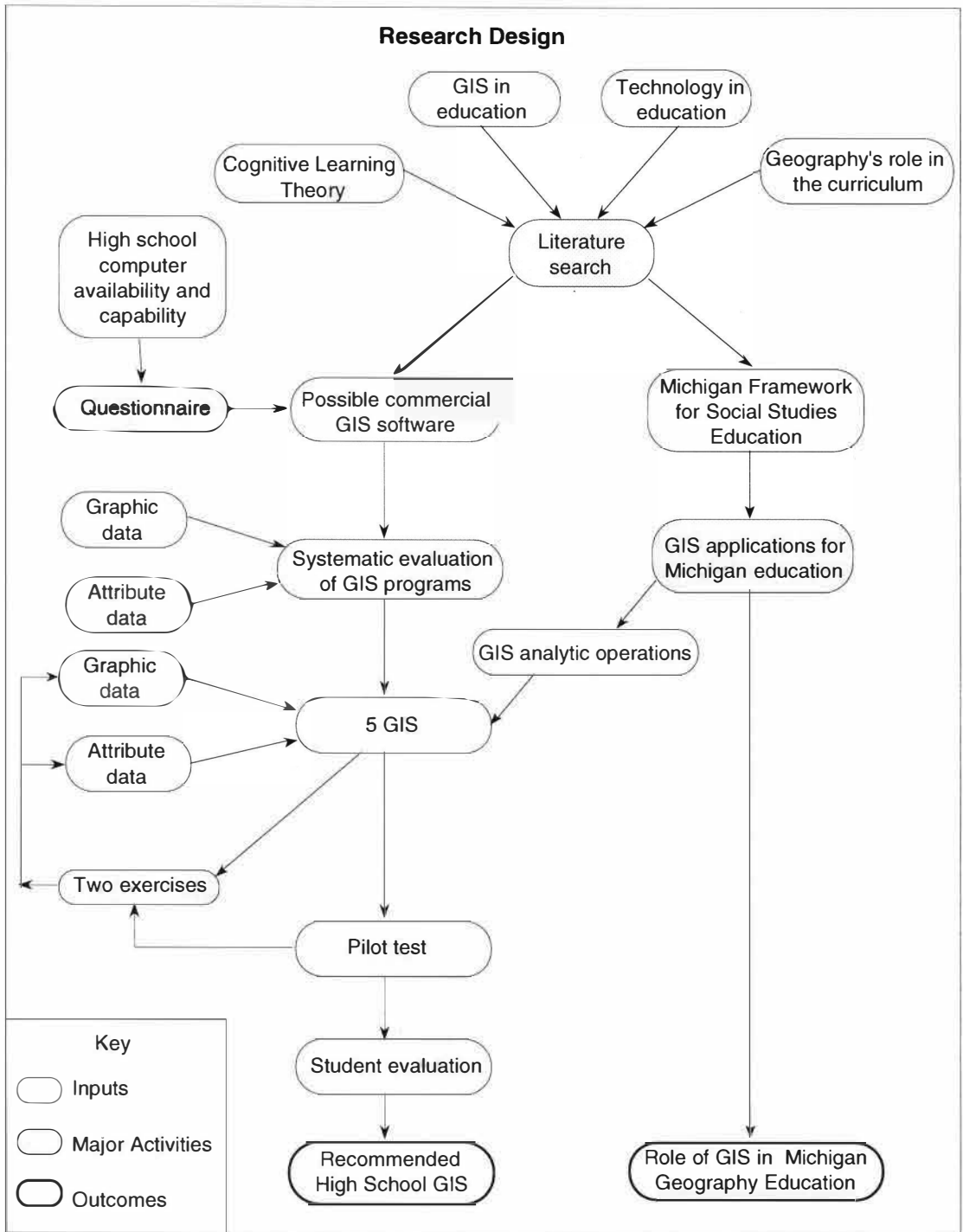


Figure 5. Flow Chart of Research Design.

CHAPTER II

REVIEW OF RELATED LITERATURE

To establish a cognitive and pedagogical rationale for employing Geographic Information Systems (GIS) in high schools, a review of current research literature was conducted. The survey was divided into four sections: the status of geography in the K–12 curriculum, technology’s role in the classroom, the implications of learning and instructional theory, and examples of GIS being used in K–12 education.

The Status of Geography in the K–12 Curriculum

Without geography, you’re nowhere.
Graffiti on Warwickshire canal bridge, UK. (Walford, 1995)

Historic Perspective

People have needed and used geography for thousands of years. The first known map is inscribed on a fragment of bone found in Mezhirichi, Ukraine and the first city map, drawn on a clay tablet from Mesopotamia, is thought to be 4,000 years old. (Gregg, 1990). Geography continued through the centuries to play an important role in the establishment of settlement and boundaries, and in pursuance of trade and war. In America, as in Europe, it was an important academic discipline in schools and colleges throughout the nineteenth century. However, the emergence of social studies in the early twentieth century lead to geography’s demise as a separate discipline in American K–12 classrooms (Stoltman, 1990). The implications of this omission was recognized as far back as 1924, when the editor of the National Geographic magazine, Gilbert H. Grosvenor (Grosvenor, G.M., 1995) noted in a memorandum:

I think it is unfortunate that children in most schools receive no education in Geography after reaching the age of 13 or 14. In these days, when the continual extension of the telephone and the radio makes instant communication between all peoples possible, and when the increasing popularity of the automobile make intimate travel comfortable and quick, it seems desirable that young people should have the opportunity in the schools to learn something of all people in all lands. And yet, the school curriculum provides no study of this subject which they may take.

The situation continued to worsen in the following decades. In the 1960s the High School Geography Project (HSGP) sponsored in part by the National Science Foundation, attempted to revitalize the subject by establishing a rigorous inquiry approach in line with the quantitative revolution which was sweeping the discipline in academic circles. Unfortunately, the HSGP was not widely accepted in schools and the subject continued to decline (Stoltman, 1990). By 1984 a University of North Carolina survey of 2,200 undergraduate students found 71% were never taught geography in elementary school; 65% had no geography in junior high; and 73% had none in high school (Grosvenor, 1995). In the previous year, the publication A Nation at Risk: The Imperative for Educational Reform (National Commission on Excellence in Education, 1983), claimed the educational achievements of a large proportion of the population were so low as to place the economic and social status of the nation in jeopardy. Data were also presented suggesting there was a serious lack of geographical knowledge amongst students (Stoltman and Wardley, 1996). Much media attention followed which focused on America's geographic illiteracy. In an extensive international survey, commissioned by the National Geographic Society in 1988, American adults ranked in the lowest third of the nine nations tested and Americans, aged 18–20, ranked last in their geographical knowledge (Gregg, 1990).

The Renaissance of Geography in the Curriculum

The response to this unacceptable state of affairs has been a renaissance of the

subject within the school curriculum (Grosvenor, 1995). This began in 1984, with the publication of Guidelines for Geographic Education: Elementary and Secondary Schools (Joint Committee on Geographic Education, 1984), which detailed the Five Fundamental Themes of Geography (Table 1). These themes were the result of a collaboration between the Geographic Education Committee of the Association of American Geographers (AAG) and the National Council for Geographic Education (NCGE), who with the help of an international panel of geographers and educators, attempted to distill the essence of the discipline into a few broad themes which could be readily understood and translated into classroom practice. The five themes have been well received by teachers and have been incorporated into texts, new state curricula, and in national testing and standards developments (Natoli, 1994).

Table 1
The Five Fundamental Themes of Geography

| | |
|-------------------------------|------------------------------------|
| Location | Position on the Earth's Surface |
| Place | Physical and Human Characteristics |
| Human/Environment Interaction | Relationships within Places |
| Movement | Human Interacting on the Earth |
| Regions | How They Form and Change |

Other initiatives have been less successful. The Geographic Education National Implementation Project (GENIP) was founded in 1985, by the National Geographic Society, AAG, and NCGE, to promote geography education. It has subsequently published curriculum guidelines, which have not received widespread acceptance (Gregg, 1990). Nevertheless, GENIP was highly successful in the establishment of

the Geography Alliance Network, which brings together academic geographers, teachers, administrators, and others interested in promoting geography education at a state level. There are now alliances in all 50 states, District of Columbia, Puerto Rico, and Ontario, Canada, which are responsible for teacher education and the dissemination of new ideas and materials into the schools (Grosvenor, 1995).

These initiatives did not go unnoticed. The nation's governors and President Bush, at their summit meeting on educational reform in Charlottesville in October 1989, chose geography as one of five core subjects to be taught in all American schools. T. J. Wilbanks (1994) has suggested that this choice was not based on an understanding of the essence of the discipline nor on a review of the five themes, but on the perception geography could provide much needed education on global economic, social, and environmental issues. Nevertheless, the educational goals established at the summit and published in The National Education Goals Report gave geography education a further boost. These goals required world class standards to be established for each of the five core subjects and for student achievement to be regularly tested (U.S. National Education Goals Panel, 1993). The latter provision led to the establishment of a framework for the NAEP geography test, first administered in 1994, which details those elements of geography which should be learnt by American students by the time they reach grades 4, 8, and 12 (U.S. Department of Education, 1994). The publication of the Geography for Life: National Geography Standards (Geography Education Standards Project, 1994) swiftly followed. These standards are intended to raise geographic education in the United States to international levels. However, as David Florio director of the National Academy of Sciences' National Systemic Initiatives program noted, national standards represent "goals that are narrative in form, not a curriculum checklist. They are intended to be an aid to state and local educators, not a prescription. They are being developed in close collaboration

with classroom teachers, who will have to ‘own’ the final product” (National Education Commission on Time and Learning, 1993). As the decision to adopt content standards is made at state or even school district level, local communities need to be convinced of the relevance of geography to the education of their students (Wilbanks, 1994).

The Michigan Perspective

Many states have begun to revitalizing the geography curriculum within schools with the drafting of content standards. In Michigan geography was incorporated as one of four disciplines in the Michigan Framework for Social Studies Education which was adopted by the State Board of Education on 19 July, 1995. The geography content standards contained in this document, while not directly based on the National Content Standards, display similar themes (Table 2). Each standard is elaborated with a number of benchmarks which specify what students are expected to know and be able to do by the end of grades 2, 4, 8, and 12 (Michigan Department of Education, 1995). How well students have achieved these benchmarks will be assessed by the Michigan Educational Assessment Program (MEAP) in grades 5 and 8, and the High School Proficiency Test in grade 11, beginning in 1999 (Michigan Department of Education, 1996). The blueprints for this test are currently being developed. Thus geography now has a state mandated role within the curriculum in Michigan.

The key milestones in the geography reform movement are summarized in Figure 6.

Classroom Implications of Curriculum Reform

The adoption of content standards and benchmarks at a state and local level is not the only hurdle to be overcome if the educational reforms are to take root. The standards are merely goals which have to be translated into teaching materials and

Table 2

A Comparison Between the National and the Michigan Content Standards

| National Geography Content Standards | Michigan Geography Content Standards |
|--|--|
| World in Spatial Terms Standards 1–3 | People, Places, and Cultures Standard 1 |
| Places and Spaces Standards 4–6 | Regions, Patterns, and Processes Standard 4 |
| Physical Systems Standards 7–8 | |
| Human Systems Standards 9–13 | Location, Movement, and Connection Standard 3 |
| Environment and Society Standards 14–16 | Human/Environment Interaction Standard 2 |
| The Uses of Geography Standards 17–18 | Global Issues and Events Standard 5 |

strategies for use in the classroom. Several studies have suggested students still function as passive learners, within the majority of the nation's social studies classrooms, using only low-order cognitive skills. Further, social studies teachers frequently have little geographical knowledge. A study of 860 teacher training institutions in 1977 found that one third required no geography credits for elementary social studies teachers and another third required only three credits in geography. In 1982 a review of state certification requirements revealed one state allowed secondary teachers to teach geography with only six credits of study in the discipline (Winston, 1986). Many teachers, probably as a result of their limited exposure to the subject, perceive geography as encompassing little more than absolute location (Marran, 1994). Therefore, if students are to meet the new standards and benchmarks, there is a critical

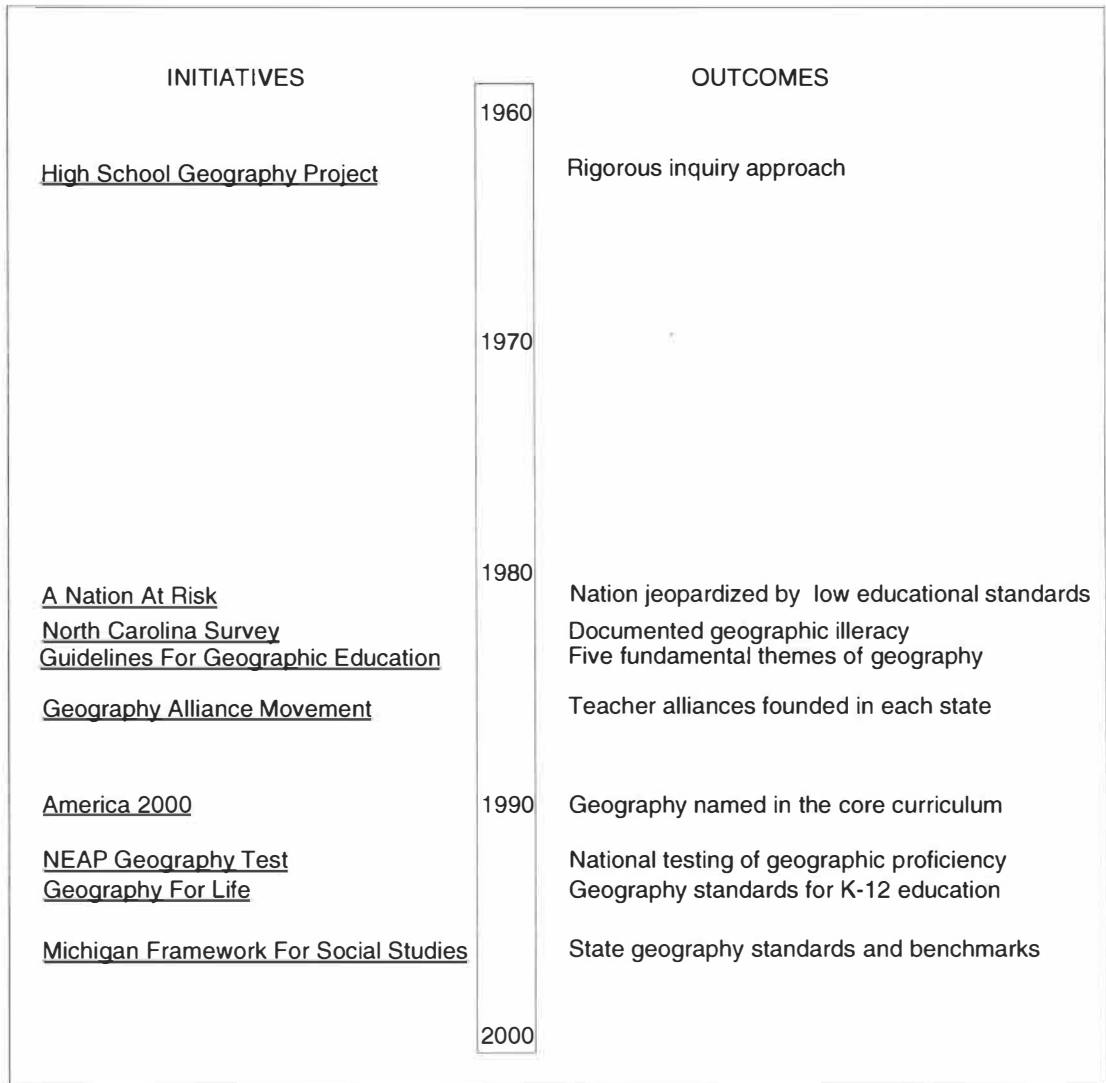


Figure 6. Timeline of Geographical Reform Initiatives.

need for the development of structured, high-level instructional materials linked to the curricular standards, along with the training of teachers in their use (Hill, 1994).

For years instructional materials in geography classrooms have tended to be dominated by the traditional textbook, or to consist of disparate fugitive materials often used with little regard for any unifying scope and sequence (Hill, 1994). In the early 1990s the National Science Foundation funded two projects, Geographic Inquiry into Global Issues (GIGI) and Activities and Readings in the Geography of the United

States (ARGUS) to produce structured geographic materials which require higher-order cognitive skills. The GIGI project developed instructional materials for secondary schools, which were designed to meet the goals of teaching responsible citizenship, modern geographic knowledge, and critical and reflective thinking. It consists of two issues-based modules for each of ten world regions (Hill, 1994). ARGUS was also developed for secondary school students and focused on the geography of the United States. It consists of four components: population geography, economic geography, political geography, and environmental geography, and is designed to help students see meaning in the landscape, to use maps analytically, and apply a spatial perspective to problem solving (Hill, 1994). Unfortunately both GIGI and ARGUS were developed before the publication of the National Content Standards. Hence, there is a need to link these materials to the standards in order to give them immediate applicability in the nation's classrooms (Hill, 1994).

Another recent project, GEOLinks, distributes over a thousand teacher designed materials on CD-ROM which can be selected by National Content Standard, keyword, grade level, learning style, cognitive level, or location (Salter & Salter, 1995). It was originally assembled to support the Minnesota geography curriculum, which supplies the scope and sequence for these lessons. Each is organized according to a standardized format which emphasizes the objectives and outcomes appropriate for the grade level. It is expected to have nationwide applicability (Hill, 1994).

Innovative materials alone cannot raise the quality of geography education, new teaching strategies are needed to encourage active learning.

The Role of Technology in Education

While much attention has been focused on the development of content standards in geography and some quality materials, little has been done to prepare new geography

teaching strategies suitable for the 21st century.

Rationale for Implementation of Computer Technologies in Education

The SCANS report for America 2000 (U.S. Department of Labor, 1992) details five areas of competency required in the workplace. These are described in Table 3.

Table 3
Workplace Know-How

Competencies—Effective workers can productively use:

| | |
|-----------------------|---|
| Resources: | allocating time, money, materials, space, staff. |
| Interpersonal Skills: | working on teams, teaching others, serving customers, leading, negotiating, and working well with people from culturally diverse backgrounds. |
| Information: | acquiring and evaluating data, organizing and maintaining files, interpreting and communicating, and using computers to process information. |
| Systems: | understanding social, organizational, and technological systems, monitoring and correcting performance, and designing or improving systems. |
| Technology: | selecting equipment and tools, applying technology to specific tasks, and maintaining and trouble shooting technologies. |

The report recommends that, “by completion of middle school, students should have been introduced to workplace know-how; by the age of 16, they should attain mastery of it; and by completion of high school, they should be sufficiently proficient in it to earn a decent living,” (U.S. Department of Labor, 1992). Opportunities for learning these skills, therefore, must become an integral part of the student’s school experience. This cannot occur if the prevalent didactic teaching methods, with their

emphasis on rote memorization, continue to dominate the classroom. Computers can, if used judiciously, provide not only experience using technology, but also opportunities for other workplace competencies, including information processing, systems analysis, and development of interpersonal skills, as detailed in the report.

Educational Benefits of Computer Technologies

Much of the research on the educational value of computer use refers to computer assisted instruction (CAI) or computer aided learning (CAL) and the various offshoots of these, such as ICAI (intelligent CAI) and ITS (intelligent tutoring systems) (Venezky, 1991). Many authors have expounded the advantages of using computers in education (Kulik, 1983; Harris, 1984; Maffei, 1986; Bullough, 1987; Jonassen, 1988; Langhorne, 1989; Venezky, 1991). These researchers suggest computers can:

1. Provide students with the capacity to acquire information efficiently, e.g., by allowing access to large data bases.
2. Provide feedback to the individual learner and allowing pacing according to the learner's capability.
3. With color graphics, provide the potential to change parameters and see effects through visualization.
4. Provide for interactive learning in which experimental and alternative ideas can be explored.
5. Allow for the development of more logical and critical thinking and help students to acquire decision-making and analytical skills.
6. Encourage students to try new things without fear of making mistakes.
7. Provide instructional experience in areas too expensive to be provided otherwise.
8. Enhance the curriculum using the special presentation capabilities of the

computer.

9. Provide possibilities for teaching new subject matter beyond the regular curriculum, particularly new topics or approaches only possible with a computer.

10. Provide opportunities for students to work collaboratively in problem solving.

All of these advantages are directly applicable to the use of GIS in the classroom, since it can provide opportunities for problem solving, experimentation, visualization, and collaborative work.

Other studies have attempted to quantify the cognitive and pedagogical gains provided by computer use. Nellis (1994) reported a number of these studies, including one in which children were found to gain the equivalent of three months of instruction per school year when computers were available to them. In another, CAL produced at least 30% more learning in 40% less time, and at 30% lower cost. When the computer was used for interactive multimedia methods of instruction, a further study found retention was raised to 80%, as opposed to 40% for discussion methods, or 20% for a lecture approach using visual aids. In contrast, other research suggests improvements may vary with ability. Kulik (1983) reported learning increased with low and high achievers, but less so with average students. Still other workers have found CAI increases enjoyment, but not necessarily learning. Kulik and Kulik (1985) reported experimental groups with access to CAI did better in terms of both grade and attitude than those without such access.

Despite some of the contradictory results of research on the value of computer use in education, teachers and researchers generally agree on a number of benefits which computers can bring to the classroom. These include:

1. Cognitive benefits—computers provide for the integration of subjects, increase time on task, accommodation of a variety of learning styles, and allow time for

enrichment and/or review.

2. Affective benefits—computers provide opportunities for peer teaching, for role modeling, increased student motivation, and opportunities for teachers to be at ease with technology (Clouse, 1991–92).

Educational Uses of Computer Technologies

To garner these benefits, computers can be utilized in a variety of different ways in the classroom. Roecks (1981) identifies thirteen educational uses of the computer, including CAL, computer literacy, computer science, as well as several administrative functions. Taylor developed an educational computer applications taxonomy which divides computer applications into three categories (Jonassen, 1988). These are:

1. Tutor—this is a device to deliver electronically programmed instruction which involves the student interactively and records and manages progress. This is more frequently termed drill and practice or computer assisted instruction (CAI).

2. Tool—this helps the students accomplish tasks quicker, more efficiently and effectively. The user initiates the activity, learns from modeling the action of the tool, and remains largely in control throughout the user-computer interaction. Examples of this are word processing and spreadsheets applications.

3. Tutee—here the student is in control by commanding the computer to accomplish some desired task. In this the user has to problem solve. An example of this includes computer programming.

GIS, while frequently termed a tool, fits better into the tutee category, since GIS requires a cognizant operator to determine which analytical operations to use to solve a problem in a meaningful way. The proactive computing environments in some GIS provide possibilities for queries not anticipated by the system designers reinforcing the tutee role of the computer (Buttenfield, 1994).

Some research has investigated the value of computers specifically in geography education (Snaden, 1988; Unwin, 1991b). Unwin (1991b) proposes four uses for the computer in the teaching of geography:

1. Computers as sources of data and information, e.g., to provide access to very large data bases which the student may actively explore, manipulate, and analyze, such as national or state demographic, political, social, and economic data and meteorological data.

2. Computers as analytical tools, e.g., statistical analysis of spatial problems, remotely sensed image analysis, computer mapping, GIS. These can be used to investigate other digital geographic information, e.g., Digital Line Graphs (DLG), Digital Elevation Models (DEM), and Geographic Names Information System files (GNIS).

3. Computers as laboratories for investigating the World, e.g., simulations to model complex world systems, which may be real or imaginary. Snaden (1988) noted role playing simulations focus on higher order cognitive processes and can be used to achieve affective objectives.

4. Computers as instructors, e.g., CAI—a programmed, self-paced course of instruction. These can include drill and practice which focuses on learning at the lower cognitive levels of factual knowledge and memorization (Snaden, 1988). Many of these programs are now camouflaged with a game format (Fitzpatrick, 1993). Others take the form of tutorials which tend to be ‘page turning’ programs of text plus graphic followed by a question.

It is important to note these authors do not envision the computer as the curriculum, but as a tool which can greatly enhance the curriculum (Langhorne, 1989) by introducing, enriching, and reinforcing a topic (Maffei, 1986).

Problems in Integrating Computer Technologies Into the Classroom

Computers have entered schools largely as a result of cultural diffusion following the acceptance of the computer in mass culture. Community initiatives by parents, students, and individual teachers have brought this technology into the classroom (Harris, 1984; Venezky, 1991). Despite the initial enthusiasm for the educational use of computers and the results of research which has reinforced the value of computers in education, they are often used for little beyond the teaching of keyboarding and basic computer skills and for drills and tutorials in many schools and colleges (Audet, 1994). Unwin and Macquire (1990), writing about higher education, suggest the reasons for this are deep-seated and social rather than technical in origin. They relate to the crude early versions of CAI, which provided very mechanistic programmed learning of factual material, the fear of unskilled academic staff and their unwillingness to invest in the effort thought necessary to enter the field, and from the idea computers are only of value as tools in the more analytical parts of the curriculum. This resulted from the inability of faculty members to recognize the enormous potential of computers for teaching virtually anything (Unwin, 1991a). These observations appear to be just as applicable to K-12 classroom. Other authors suggest the early projections of computers driving the much needed revolution in education raised expectations beyond what could be delivered, resulting in disillusionment with the technology, and leading Venezky (1991) to propose a need for more modest goals for CAL as a cost effective approach to instruction. Venezky (1991) also pointed out that any new teaching method has to prove its ecological validity by being so much better than existing methods, to justify the institutional costs and anxieties caused by change. In one of the few comparative studies of learning using GIS, K. Weller (1993) examined "The Appropriateness of GIS Instruction in Grade Six for Teaching Kansas

Water Resources” in which sixth grade students used manual or computerized GIS for ten twenty minute periods over a two week period. The classroom which used the computerized GIS did not have sufficient computers to allow the students to interact with the computer for the entire ten lessons. This limited exposure to computerized GIS did not produce any measurable improvement in learning.

These issues have to be resolved if geographic education is to be enhanced by the integration of computer spatial applications such as GIS. Such software can provide students with unrivaled opportunities to understand and model geographic patterns and processes (Nellis, 1994). Training students to use these technologies will also address the future needs of the workplace, especially in information, systems, and technology competencies, as outlined in the SCANS Report for America 2000 (U.S. Department of Labor, 1992) (Table 3).

The Pedagogical Implications of Learning and Instructional Theory

Cognitive learning theories attempt to explain how learners employ cognitive processes to create meaningful information in the memory from instructional stimuli (Happs, 1985). Psychologists have long debated the issue of how humans learn. Within the twentieth century two very different bodies of theory have been developed.

Historic Perspective

In the first half of the 20th century psychological research in United States was dominated by behaviorism, in which learning was thought to result directly from sensory experiences. It focused on identifying the environmental stimuli which brought about the desirable response in learning; for example, memorization in the learner which may be then reinforced or weakened as a result of additional experiences. Significant contributions were made to this body of theory by E. L. Thorndike, Ivan

Pavlov, and B. F. Skinner. In contrast to this largely empirical approach to the study of learning, European psychologists at this time saw learning in terms of rationalism, where the environmental stimuli were interpreted by the learner using innate cognitive processes (Shute, 1994). This approach was developed, particularly in Germany, by Gestalt psychologists who focused on the structural characteristics of mental functioning (Shuell, 1994). Gradually both orientations began to coalesce.

In 1932, F. Bartlett developed the theory of schemata or mental structures in which past experiences are used to interpret new knowledge and give it meaning. The idea of schema had been first hypothesized by Head, a neurologist, in 1918 (Brewer, 1984). The Swiss psychologist, J. Piaget, believed these cognitive structures were not innate, but were developed through the active acquisition of knowledge and evolved through childhood into maturity (Shute, 1994). The Soviet psychologist, L. Vygotsky, saw cognition being influenced not only by maturation, but also by cultural factors which provided the foundation for cognitive processes. This holistic activity approach did not influence learning theory for several decades (Strauss, 1993).

By the 1960s the zeitgeist of American psychology began to swing from a behaviorism to constructivism, as the emphasis moved from changing the environment in order to influence learning to encouraging the use of appropriate learning strategies (Shuell, 1986). Learning was no longer thought to be merely a passive response to environmental stimuli, but an active constructive process. In the 1970s, research concentrated on analysis of memory, problem solving, and language. This cognitive psychology brought several new concepts to learning theory, including: (a) learning as an active, constructive process; (b) learning encompassing higher level cognitive processes; (c) learning as a cumulative process in which prior knowledge is influential to learning; (d) cognitive structures in which knowledge is represented and organized in the memory; and (e) the analysis of learning tasks and performance in terms of the

cognitive processes involved (Shuell, 1986). Theories of learning seek to explain how these cognitive processes are engaged during learning.

Modern schema theory has been developed by many researchers, including Minsky and Rumelhart and Ortony, who sought to explain how new knowledge is constructed by a process of creating personal meaning from new information and prior knowledge (Brewer, 1984). In this theory, information is stored in the brain as a mental picture or schema, which is constructed by direct, active exploration and learning. New information is processed into new knowledge by linking it with existing schemata, that is prior knowledge, or developing a new schema to accommodate it (Conley, 1992). Higher order thinking involves the manipulation of information to produce new meaning or comprehension, such that new information can be accommodated within schemata. Only then does learning actually occur.

This idea is further developed in D.E. Rumelhart and D.A. Norman's theory which describes three different kinds of learning, these are: (1) accretion in which new information is encoded in terms of existing schemata, (2) restructuring or schema creation when new schemata are made, and (3) tuning or schema evolution in which schemata are refined as a result of experience in different situations. L.B. Resnick has suggested accretion and tuning are similar to the processes of assimilation and accommodation in Piaget's theory of cognitive development (Shuell, 1986).

Many learning theories do not consider the influence of instruction on these cognitive processes and it was not until the 1980s that instructional psychology became a separate part of cognitive psychology (Shute, 1994).

Cognitive Learning and Instructional Models

While theories of learning attempt to describe the behavioral and cognitive processes involved in learning, models of learning form a practical application of those

theories to groups of students in classrooms by identifying the principles, variables, and concepts which support learning. They can also be used to generate instructional models for implementation in schools (Burns, 1994).

A model of school learning developed by J. Carroll in the 1960s related the degree of learning to the time spent on task in relation to the time required to complete the learning task. A ratio of 1:1 indicated learning was accomplished. Three variables, motivation, opportunity to learn, and time allowed, were thought to influence the time spent learning, while aptitude, intelligence, and quality of instruction governed the time needed to learn. This model gave rise to the well known concepts of learning rate, engaged time, and active learning time which emphasize the importance of time in student learning (Burns, 1994).

Also in this period, J. Bruner developed a model of instruction which focused on identifying conditions which improve and optimize learning outcomes. Four factors which influence learning were outlined. These included: (1) learner predispositions—these are the motivational factors which influence learner's desire for learning, (2) structure of knowledge—how the knowledge to be learned is represented, (3) sequence—the order in which the information is presented, and (4) timing and nature of reinforcement—this relates to feedback on how the learning is progressing. Bruner argued for students to be involved in diverse opportunities through which they can develop greater understanding and integration of knowledge and skills (Burns, 1994).

Other researchers have also stressed the importance of students actively processing new information if effective learning is to take place. M. Wittrock's Generative Learning Model suggests learning with understanding is a function of the associations which the learner generates between prior knowledge stored in the long term memory and the new stimuli. New meanings and interpretations of events are constructed by actively retrieving information from long term memory and using

information processing strategies to generate meaning from the new information, which is then organized, coded, and stored in the long term memory (Wittrock, 1974). Happs (1985) considers Wittrock's model compatible with the Piagetian constructivist approach.

R. Gagné and R. White proposed long term memory consists of four types of elements: (1) verbal knowledge, (2) intellectual skills, (3) images, and (4) episodes. The verbal knowledge contains facts or beliefs; intellectual skills consists of information on task performance; while images are pictorial or diagrammatic representations of information; and episodes are memories of events in which the individual took part. Gagné and White suggested recall of any element is a function of the degree of interlinking with other elements within the memory, therefore, learning experiences which involve all four elements are likely to improve retention of related factual material within long term memory (Gagné and White, 1978).

More recently cultural psychology, influenced by sociocultural work of Vygotsky, has proposed the use of authentic learning activities in a model of learning and instruction called "Cognitive Apprenticeship" (Shuell, 1994). In this context, authentic activities are those which simulate situations the student will encounter in life outside the classroom. Traditionally school learning has not been placed within the context of the real world experiences and social interaction and consequently, has not harnessed the innate curiosity and desire for knowledge and social contact of the students (Burns, 1994). In this Expert-Novice model, the teacher demonstrates the authentic learning task and students work in groups to emulate the expert performance. The group activities are designed to provide a supportive learning environment for the students and to distribute work across the group. Gradually external support is removed as learners assume more responsibility for their learning (Burns, 1994). Strauss (1993) noted that in this model, the apprentice's cognitive knowledge structures

differ in several ways from the expert's, particularly in knowledge content, organization, and problem solving strategies. Therefore, students require diverse learning opportunities to move from novice to expert status.

Learning theory demonstrates knowledge is acquired in a variety of ways. Simple learning may be facilitated by operant and classical conditioning, whereas meaningful learning of complex material is an active, constructive, cumulative, self-regulated, and goal-oriented process. This latter type of learning is concerned with understanding of a complex body of knowledge and the establishment of relationships between concepts and facts as opposed to the memorization of separate isolated facts found in simpler forms of learning (Shuell, 1994).

GIS as an Instructional Tool

The fundamental theoretical foundation for moving GIS technologies into the K-12 classroom is based on cognitive, not behavioral, systems, or management theories, all of which have been applied in the past to CAI, but which are more concerned with educational and instructional management (Winn, 1988). The question is whether using a GIS can facilitate effective learning of complex materials.

Instruction must engage students in learning activities which are likely to result in effective learning, taking into account prior knowledge, the context in which the material is presented, and the realization that the student's interpretation and understanding of new information depends on the availability of an appropriate schemata (Shuell, 1986). Because of the wealth of information available today and the different experiences each learner brings to the classroom, the teacher must provide the links between new information and prior knowledge, and design activities which accommodate all types of learning (Happs, 1985). Further, the social and cultural nature of learning has to be taken into account with the provision of authentic rather

than artificial tasks and the consideration of motivational and affective influences on learning.

Not all the models of learning and instruction appear directly applicable to learning with GIS. However, most models indicate the importance of active information processing in learning. Students using GIS must employ higher order cognitive skills when manipulating data if meaningful results are to be obtained. The Gagné and White model of learning suggests learning experiences which involve the four elements of verbal knowledge, intellectual skills, images, and episodes, are likely to improve retention of related factual material within long term memory. A concept taught using a GIS would provide all four elements: (1) factual information involving the context in which the concept is embedded; (2) intellectual skills generated in the manipulation of this information; (3) image in the form of the various map layers; and (4) an episode when the student performs the task at a computer terminal. It may be pertinent to add at this point that the strength of event or episodic element may decrease as computers become part of the everyday experience of the classroom. Similarly, instruction with a GIS fits well with the Expert-Novice model. R. Audet (1993), in his study on "Developing a Theoretical Basis for Introducing GIS into High School: Cognitive Implications," found GIS experts employed very different methods of problem solving than novice high school students. It is, therefore, apparent GIS will not teach students problem solving skills, but the teacher as the expert can model complex problem solving strategies with authentic tasks using a GIS, which groups of students can emulate as they learn the cognitive processes involved. Table 4 summarizes the instructional benefits of utilizing a GIS for effective learning.

Using a GIS allows students to manipulate information, investigate relationships, and create their own meaning. It also provides opportunities for analysis of real world or authentic problems in an environment which allows for self-pacing and

Table 4
Instructional Benefits of Using GIS

| Methods for Effective Learning | GIS Facilitates |
|---|-----------------|
| Gagné and White's Model: | |
| Factual knowledge | √ |
| Intellectual skills | √ |
| Images | √ |
| Episodes | √ |
| Expert-Novice Model: | |
| Problem Solving strategies | √ |
| Authentic tasks | √ |
| Investigatory approach | √ |
| Higher order cognitive skills | √ |
| Self-pacing | √ |
| Opportunities for collaborative learning | √ |
| Accommodates a variety of learning styles | √ |
| Motivation | √ |

a variety of learning styles (Tennyson, 1988). Data manipulation with a GIS involves the higher order thinking skills of classifying, comparing, contrasting, generalizing, hypothesizing, and drawing inferences and conclusions. Hence, by using GIS students can actively investigate spatial relationships, develop a deeper understanding of the underlying geographical concepts, and attain more meaningful learning.

Examples of GIS in K–12 Geography Education

Although the potential for using GIS in K–12 has generated enthusiasm among professional educators, as demonstrated by the EdGIS conference in January, 1994 and the specialty meeting at the National Council for Geographic Education in November, 1996, there is little evidence of its widespread acceptance in schools. Nevertheless there have been a number of initiatives designed to encourage the adoption of GIS by schools.

The National Center for Geographic Education and Analysis (NCGIA), authors of a GIS core curriculum for post-secondary education, established the Secondary Education Project (SEP) in 1992. The Project has sponsored a number of teacher workshops which provide a short basic introduction to GIS and some digital data sets which can be used with the GIS programs, IDRISI and ArcView (Palladino, 1994). Environmental Systems Research Institute (ESRI), the manufacturer of ArcView, created the “Adopt-a-School” program in 1992 in which the company supplied low cost software and data to selected schools and encouraged local government and private business GIS users to share data and expertise with the adopted school (ESRI, 1995). Teacher training was undertaken by government and private agencies or through university programs, some of which were sponsored by state Geographic Alliances. By 1994 nearly 250 schools were enrolled in the program (Wendelken, 1994). ESRI has also provided software to each of the fifty state Geography Alliances, which run demonstrations and workshops at summer institutes for teachers (Fitzpatrick, 1994).

Despite these initiatives there are only a few documented instances of well established GIS programs in secondary schools. At the Thomas Jefferson High School for Science and Technology, a magnet school in north Virginia, two GIS software packages, IDRISI and ArcView, are being used in a geoscience class. Here students

have classified Landsat images of the 1988 Yellowstone National Park fire, the 1993 Mississippi floods, and the Gulf War oil fires of Kuwait using GIS, as well as conducting studies of local watersheds and solid waste disposal sites (Keranen, 1994). Another year-long GIS curriculum is offered in environmental science at the Jupiter Community High School in Palm Beach, Florida (Ramirez, 1995). In Ohio, the 200 acre campus at the University School is used as a field laboratory in a GIS and Environmental Science curriculum (Friebertshauser, 1994). In Michigan the students at Cass Technical High School in Detroit, have mapped the location of 200,000 homes serviced by lead water mains. The maps are being used by the City of Detroit and the School of Public Health of the University of Michigan to identify at-risk students. The Cass GIS students are involved many other similar community service projects (Raymond, 1994). In Kansas, a network of teachers and students from across the state are involved in an environmental monitoring project. In one school students are using GIS as part of a national study of Monarch butterfly migrations, while other students are monitoring non-point source pollution in a local watershed (Case, 1994).

All these projects highlight some of the inherent problems of moving GIS technology into schools. Firstly, in at least two of the schools, north Virginia and Florida, GIS is only available to high achieving students. For example, in the Palm Beach school, only teacher recommended, honor students, who have already studied earth science, advanced mathematics, geography, and have computer literacy, may take the course (Ramirez, 1995). This reflects the universal difficulty in using complex GIS software. Secondly, many of these schools have the opportunity to use GIS because they are technologically well equipped, as all full-functioned GIS systems use sophisticated hardware. The ESRI "Adopt-a-School" program addresses this problem by encouraging fund-raising events to finance the necessary hardware to run ArcView. Thirdly, although many of the teachers in the schools listed above have had little formal

GIS education, they are extraordinarily talented and motivated. Typically extensive teacher training is necessary before GIS can be introduced into the classroom. The South Florida Water Management District provides 60 hours of GIS training to interested teachers, followed by additional studies at national GIS conferences (Ramirez, 1995).

Conclusion

Modern technology is used in almost every work place in the United States. It, therefore, must be an integral part of the student's school experience. Extensive research has shown the use of computers can enhance the curriculum by providing numerous cognitive and affective benefits and the technology also now has the potential to provide access to vast information resources and to facilitate analysis, problem solving, and systems modeling. As geography is being endowed with new authority in the K-12 curriculum by national and state goals and content standards, GIS seems ideally poised, as a computerized system which encompasses the peculiarly geographical domain of spatial relationships and demands the use of higher order cognitive processes, to move geography into a new era in K-12 education. Some of the practical considerations of this lofty ideal as well as an examination of the role of GIS in a standards-based Michigan geography curriculum are the focus of this research thesis.

CHAPTER III

GEOGRAPHIC INFORMATION SYSTEMS IN THE GEOGRAPHY CURRICULUM

Introduction

The first part of this research sought to define how Geographic Information Systems could be integrated into high school geography curriculum in a selected region of southwest Michigan. Efforts to elucidate the role of GIS in higher education have fueled a vigorous debate for over a decade. As yet little has been written on the subject with respect to K–12 education. However, many of the issues are the same in both arenas, although their resolution is likely to be quite different. These issues can be consolidated into three research questions:

1. What are the educational ramifications for the integration of GIS into the curriculum?
2. How much education and training will teachers and students require to use GIS effectively?
3. Can GIS be integrated into the high school geography curriculum in Michigan?

Educational Ramifications of GIS

Three of the principal concerns educators raise in the post-secondary GIS controversy will be discussed with reference to the high school curriculum in Michigan.

GIS Education Versus GIS Training

GIS is becoming a widespread phenomenon for the management and analysis of spatial information. As much as 80% of all information held by business and government may be geographically referenced (Franklin, 1992) and the realization of this has resulted in GIS becoming a multi-billion dollar industry with a growth rate of 20–30% per year (Barstow, 1994). Such rapid growth has quickly out-stripped the supply of GIS educated and trained personnel, resulting in many technicians working in the field with little formal GIS training. A survey by Medyckyj-Scott and Hearnshaw in Europe and Australia found 37% of the 51 respondents had 2 weeks training, 24% 1 to 2 weeks, and 33% less than 1 week (Hearnshaw, 1993). This has raised the most critical and controversial question of who should train GIS specialists. Few seem to argue GIS is not a necessary part of any collegiate geography curriculum, as GIS is the tool of choice for the analysis and modeling of spatial data and associated nonspatial or attribute information (King, 1991). Nevertheless, many academics challenge a technocentric vocational approach to education (Kemp, 1991). Their concern focuses on the increase in technical training being at the expense of overall geographic education (King, 1991). This debate has been waged particularly vociferously in Britain, where many scholars believe the university's role is to educate, not to vocationally train students. These academics maintain training should be provided by software manufacturers or in short post graduate training programs (Jenkins, 1991). In the United States many universities now offer courses which teach the conceptual framework of GIS, even so there is still some controversy as to how much technical proficiency should be achieved. Walsh (1992) called for the integration of GIS education and GIS training as the most effective way to teach GIS. While the universities continue to argue about their role in GIS education, the junior colleges are

beginning to address the demand for technically trained personnel, by instigating GIS courses which provide some conceptual background with specific technical training (Palladino, 1995; Holley, 1996).

Does this contentious issue translate directly to the K–12 arena? Some believe it does. With business and government clamoring for trained personnel, secondary education in GIS is seen as necessary to alert students to the possible job opportunities in the industry, especially if technical training becomes widely available in community colleges (Barstow, 1994, ARCNews, 1995). This view would seem to be reinforced by the SCANS report for America 2000 (U.S. Department of Labor, 1992) which recommends high school students should attain proficiency in using computers to process information; in understanding technological systems; in monitoring and correcting (system) performance; designing or improving systems; in selecting equipment and tools; applying technology to specific tasks; and maintaining and troubleshooting technologies (Table 3). Using a GIS to teach geographical concepts would involve many of these skills. How much education or training this K–12 exposure to GIS technology would involve has not been widely discussed.

GIS as a Science Versus GIS as a Tool

Recognizing a need to incorporate GIS into the curriculum raises another dichotomy. Does this mean education about GIS or with GIS? Many universities seem to be choosing to educate about GIS by offering GIS courses, frequently at the graduate level. Some undergraduate courses are being developed or GIS modules are being incorporated into existing spatial techniques courses (Walsh, 1992). The National Center for Geographic Information and Analysis (NCGIA), responding to the industry's need for trained personnel, developed a collegiate core curriculum to encourage the initiation of quality courses in GIS and to provide a standard for what

students educated about GIS should know (Kemp, 1991). This year-long course is divided into three sections: Introduction to GIS; Technical Issues in GIS; and Application Issues in GIS.

Even though the SCANS report (U.S. Department of Labor, 1992) emphasizes the importance of the technological training, many educators do not believe there should be a similar GIS curriculum in secondary schools (Tinker, 1994). The Edgis meeting, a GIS in K-12 education specialist group, at the NCGE conference in Santa Barbara, California, in November 1996, came to the conclusion there would always be a few schools which could offer a GIS curriculum, for example, as an elective in science and technology magnet schools. Students studying such a curriculum would receive the appropriate social studies or science credit for the content discipline in which the curriculum is embedded. In the majority of schools, however, GIS would be used as a tool within a number of different disciplines. The curricular requirements of a GIS course will be quite distinct from those engendered by using GIS as a tool.

No core curriculum for GIS has been developed at secondary level and there is as yet no consensus among educators as to what such a GIS curriculum should include. Therefore, schools which wish to institute a GIS curriculum have no relevant research to guide the development of their courses.

If, on the other hand, GIS is to be used as a tool, what is it essential to know about GIS theory to successfully use a GIS? This issue has not been resolved at the university level where GIS is being used in a wide spectrum of disciplines, from landscape architecture, environmental science, engineering, forestry, urban and regional planning, to geography (Walsh, 1992). In business and government, GIS is increasingly utilized by the casual user who is not trained in GIS technology nor theory. As GIS interfaces become more user friendly, this trend is likely to increase. How much knowledge do such users need to produce accurate and meaningful results?

White and Simms (1993) see danger in GIS driving the methodology of problem solving in these situations. If the user does not first develop a true understanding of the question, the GIS could take on the aura of a 'magic box'. Walsh (1992) expresses similar concerns that the casual user will conduct analyses with insufficient understanding of conceptual and analytical considerations. To counteract technology driving decision-making Chrisman (1987, 1997) has suggested the GIS curriculum should not be centered on GIS software operations but structured around the nature of geographic information and how GIS processes are dependent on social and cultural contexts. Again there is no body of research in this field with respect to secondary education. How much GIS theory would the teacher and the student need to know to successfully utilize this tool? Research is needed to resolve these issues before successful widespread implementation of GIS can occur.

Commercial Versus Educational Software

The third contentious issue in GIS education and training is which type of software to use. Rogerson (1992) ponders whether an academic program can or even should use a commercial software package. Other authors express frustration at the high cost of hardware and software necessary for introducing GIS into the curriculum, and the frequently recurring costs of maintenance and upgrades which prevent small and less well-funded university departments from offering their students exposure to industry standard GIS (Wise, 1991, Wilke, 1991). Campbell (1991) promotes the use of a spreadsheet as a low cost GIS, and Unwin (1991b) believes the most basic GIS concepts and principles can be taught at an introductory level using relatively low cost software, e.g., ARC/DEMO and its successor, GIST!, and GISTutor (Raper, 1992). GIS software available in the public domain can also be used, e.g., ArcView 1.0, OZgis, and TNT MIPS Light. Wise (1991) describes a British initiative to centrally

purchase a commercial program which could be made available to campuses at reduced costs. Such discussion becomes moot when employers continue to select candidates for GIS related jobs who have had hands-on experience with a particular commercial software package, despite protestations that they want well-educated and well-rounded employees (Rogerson, 1992). This returns full circle to the issue of the universities' role in education or training. The reality of the job market may indeed resolve both issues regardless of the opinions of the academic purists.

This latter consideration is of no particular consequence in the K-12 arena. No one expects a high school student to become sufficiently proficient to enter directly into the work force as a GIS technician. Despite this, the question of which software to use is equally problematic, but for different reasons. As there are no programs specifically designed for secondary education, schools have no alternative but to use higher educational or commercial packages. The suitability of these programs for high school education is investigated elsewhere in this research (see Chapters IV and V).

Learning to Use a GIS

GIS are only as useful as the information the users can gain from them.
(Andrew Frank 1993, 12).

This statement reaches to the very heart of the problem. Generating meaningful, comprehensible information with a GIS can be very difficult and frustrating, particularly for the novice. How do we prepare students to make the necessary, huge leap in understanding within the constraints of the high school curriculum?

It is quite clear students will not be able to use a GIS as a tool without some education and training. Hearnshaw (1993) recognizes four types of learning in training a GIS user: (1) education about GIS, (2) education with GIS, (3) training about GIS,

and (4) training with GIS. Education refers to the learning of GIS concepts and GIS applications, and training is learning which is software and hardware specific. This format will be used to discuss the GIS education and training of high school users.

Education About GIS

How much the student needs to know about GIS theory to effectively use the system as a tool cannot be accurately answered as yet. Personal experience in operating GIS software would seem to indicate certain prerequisites are essential. For instance, students will need initially to know the types of data a GIS can handle and how these are encoded. GIS is ideally suited to process spatial data which is geo-referenced, but people do not think spatially in terms of the arcs, nodes, and polygons of a vector system nor in terms of the pixels of a raster system. Consequently, significant cognitive and behavioral modification has to occur to understand and manipulate these spatial depictions (Medyckyj-Scott, 1991). This became apparent in this research when the majority of the students in their brief exposure to GIS failed to grasp the significance of the mode of data encoding on the results of the analysis they conducted, even though it was pointed out to them (Chapter V). Students also require an accurate cognitive map of the data base and of ways a GIS can display this information, if they are to appreciate and exploit it fully (Blades, 1993).

Secondly, although many students and casual users may never enter data, especially as more digital data becomes readily available, sources of data and methods of entry are important in understanding the accuracy and limitations of the data for analysis. Even though some schools will be involved in community GIS projects where accuracy is a critical factor in decision making, e.g., Cass Technical High School (Raymond, 1994), curriculum restraints will limit the majority of the projects undertaken in high schools to the teaching of concepts and not in solving community

problems. For students to fully understand data constraints, it would be advantageous for students at some stage to develop their own database from paper maps or field survey. This would be in-line with cognitive learning theories which stress the importance of students actively processing new information for effective learning. Not all systems support tablet digitizing and it is unlikely schools will be able to purchase the necessary additional hardware and software for such occasional use. Many systems, however, do allow for the screen digitizing of scanned maps or images. Data acquisition is frequently taught first, mimicking the beginning of any GIS project, but the more fundamental implications of data entry can be missed as the student struggles with the mechanical issues of operating the hardware and software. System familiarity may be necessary for the full ramifications of data entry to be realized. Knowledge of data entry may also be necessary for the overall comprehension of the system. The students who participated in this research specifically asked how the maps were entered into the GIS.

The third necessity is an understanding the range of analyses GIS can perform and where these can be applied. Coulson and Waters (1991) found college students, in introductory level GIS courses, frequently employ inappropriate analyses and demonstrate a lack of understanding of the statistics used. In the high school where GIS is used as a tool, the teacher will have to assume responsibility to guide students away from these pit-falls. This implies the teacher has a comparatively advanced knowledge of GIS, which is seldom the case. These problems serve to highlight the depth of knowledge required by the teacher will be very different from that required by the student who uses GIS as a tool to conduct inquiries.

Fourthly, knowledge of principles of data display and output is necessary since the purpose of using a GIS is for visualization of information. Most systems allow for a variety of display modes, including graph, table, map, text, image, and photograph

and a few even incorporate audio and video. Some permit the display of all of these on a single screen. For such output to have the desired impact some graphing, cartographic, and artistic knowledge will be needed, if appropriate choices are to be made. Geographers frequently bemoan the garish maps shown in GIS advertisements and magazines designed by the cartographically illiterate for instantaneous visual gratification, but which lack meaning. Medyckyj-Scott (1991) suggests GIS should have minimum default values based on map design principles to avoid the production of poorly devised, ineffective maps. In the high school setting, it is to be hoped the students will have acquired graphing and cartographic skills from previous mathematics and geography courses, prior to working with a GIS. This indeed will be the case in Michigan if they have attained proficiency in the geography content standards and benchmarks for the previous grades (Michigan Framework for Social Studies Education, Michigan Department of Education, 1995).

Apart from an introduction to GIS, the learning of most of this information can be integrated into GIS projects. In fact teaching the fundamentals of GIS in a situation where theory is not divorced from performance will probably be the most effective strategy. This requires that the first GIS projects be carefully structured to introduce the concepts one at a time, so that students have the time to assimilate the new knowledge into existing schema or construct a new schemata before application is required.

Training About GIS

Before students can use GIS effectively they have to learn how to operate the hardware and software. This can be so time consuming some high school GIS courses demand computer literacy as a pre-requisite for participation (Ramirez, 1995). Even with knowledge of the hardware, learning to use the software is not easy. Although

many programs now use a more user-friendly Microsoft Windows interface standard, the learning curves can be quite long and steep. This is a significant problem in a situation in which GIS will be used as an occasional tool in a social studies course, which may be already overburdened with too much content. Nevertheless, students still have to be trained in the appropriate skills and behavior patterns for specific GIS tasks, beginning with information on the overall structure of the system and the procedural steps to do basic tasks, e.g., start, stop, assess a file, and save a file (Hearnshaw, 1993). Only through knowledge of the file structure and methods of retrieval can appropriate files be assembled for use as a project.

Once these essential skills have been mastered, students can learn to manipulate maps by changing the scale and performing visual overlays of compatible map layers. All systems allow for querying of maps and the database and for some analyses, hence, students require training in the querying process and in how the GIS performs individual analyses. In a raster system, maps may require recoding prior to or as a part of data manipulation, if map objects are to remain distinguishable. In addition detailed knowledge of the operation is often necessary in order to interpret the results. In a vector system the user can be less intimately involved in the individual operations, even so an analysis frequently has to be conducted in stages in which tables may require joining or intermediate maps constructing. Finally, the student will have to be aware of the display capabilities of the system and learn how to color a map appropriately and create a layout which effectively shows the information. Some of the basic skills needed to operate a GIS are shown in Table 5.

Education and Training With GIS

These two types of GIS learning will be treated together as they are intrinsically interwoven. Education and training with GIS is essentially where students are educated

Table 5
Some Basic Skills Needed to Operate a GIS

Cartography

Changing scale and selecting map projections.
Subsetting data.
Classifying data.
Choropleth maps.
Choosing symbols and colors.
Overlay.
Querying a map by logical expression or spatially.
Map analysis.

Manipulating tables

Restructuring a table.
Sorting a table.
Querying a table.
Joining tables.
Joining a table to a map layer.

Graphics

Choosing graph types.
Selecting numerical scales

Table 5—Continued

Layouts

Combining appropriate maps, tables, graphs, and text.

Creating effective maps.

Source: Adapted from *GIS in K–12 Education*. ArcView White Paper Series. Redlands, CA.: Environmental Systems Research Institute, April 1995.

in how GIS can be used to study other disciplines, e.g., geography, earth science, biology, or environmental science, and receive training in manipulating a particular system to solve specific topical problems.

It is important not to lose sight of the cognitive and curricular constraints of the high school classroom, when realizing the potential of using this new technology to involve students in exciting investigatory research. Firstly, there is a need to analyze the cognitive demands of GIS tasks to ensure the students have the cognitive prerequisites to understand or learn the task (Liben, 1994). This will be less of a problem in high school grades than with younger children. Although there is no research data on the cognitive development levels necessary for specific GIS tasks, in this research there was a noticeable difference in the speed and depth of concept assimilation between the 9th grade and the 11th and 12th grade students. This could pose significant problems in high schools where geography is open to all grades. Even so, this situation could also provide opportunities for cooperative learning where older students work with and help the younger students.

Secondly, where GIS is used as a tool, any GIS project must meet the aims and objectives of the curriculum in which it is used (Jenkins, 1991). Many school curricula are becoming content standard driven. This is particularly so for many disciplines in

Michigan. The Michigan Framework for Social Studies Education contains content standards for the four Social Studies discipline strands of history, geography, civics, and economics, and the three cross-cutting strands of inquiry, public discourse and decision making, and citizen involvement (Figure 7). The content standards of these latter strands will be achieved within the context of the four social studies disciplines. Benchmarks for each content standard have been established to designate what students are expected to know and be able to do at the end of early elementary, late elementary, middle, and high school grade levels (Michigan Department of Education, 1995). These benchmarks are to be used as the basis for state-wide assessment in grades 5, 8, and 11, beginning in 1999. This assessment is linked to state funding of schools and maintenance of local control of schools. Therefore, with such high stakes state assessment, it is readily apparent that any integration of GIS into the geography curriculum will have to address the discipline's content standards and benchmarks.

The content standards not only incorporate the content of the curriculum but the methods by which it is taught. The cross-cutting content standards promote an inquiry approach to geography education. This is further reinforced by the Standards for Teaching (Michigan Department of Education, 1996) which encourage the development of lessons which involve students in higher order thinking, deep knowledge, and connections to the world beyond the classroom. This is in-line with current cognitive learning theories which stress the importance of the active acquisition of knowledge through authentic learning tasks. GIS is particularly suited to an inquiry approach to learning. The Michigan high school content standards and benchmarks for the geography and cross-cutting strands are shown in Figures 8 and 9.

Typically the development of curricula is determined at a school district level in Michigan. However, by virtue of the state recommended core curriculum and state mandated assessment, the scope and sequence of geography curricula in Michigan

| SOCIAL STUDIES STRANDS AND CONTENT STANDARDS | | | | | | |
|--|------------------------------------|---------------------------------------|----------------------------------|---------------------------|---|------------------------------|
| <u>Historical Perspective</u> | <u>Geographic Perspective</u> | <u>Civic Perspective</u> | <u>Economic Perspective</u> | <u>Inquiry</u> | <u>Public Discourse and Decision Making</u> | <u>Citizen Involvement</u> |
| Time and Chronology | People, Places, and Cultures | Purposes of Government | Individual and Household choices | Information Processing | Identifying and Analyzing Issues | Responsible Personal Conduct |
| Comprehending the Past | Human/Environmental Interaction | Ideals of American Democracy | Business Choices | Conducting Investigations | Group Discussion | |
| Analyzing and Interpreting the Past | Location, Movement, and Connection | Democracy in Action | Role of Government | | Persuasive Writing | |
| Judging Decisions from the Past | Regions, Patterns, and Processes. | American Government and Politics | Economic Systems | | | |
| | Global Issues and Events | American Government and World Affairs | Trade | | | |

Figure 7. Michigan Social Studies Strands and Content Standards.

Source: Michigan Department of Education. Michigan Framework for Social Studies Education: Content Standards. Michigan Social Studies Education Project, July 1995.

schools can be determined. The context for the MEAP tests are shown in Figure 10. As can be seen the regional emphasis at the lower grades changes to a thematic approach in high school geography in the form of Global Issues. Therefore any program to integrate GIS into the classroom must be within this context. Most of the current initiatives for using GIS in the classroom have focused on local issues (Keranen, 1994; Raymond, 1994; Case, 1994; Friebertshauser, 1994). Indeed this is the recommended approach for the integration of GIS into the curriculum (Audet, personal communication, 1996; ESRI, 1997). This has largely arisen from instances in which students use field work to collect their own information to build databases and from the perception that students learn better when studying issues which are close to them geographically as well as emotionally. Further, digital data are often easier to obtain from local government agencies and businesses. Michigan's global context for high school geography curricula does not totally preclude the use of local data. In a thematic approach, traditionally the basic principles of a process are taught first and then illustrated with case studies, and where possible, one with a local or national focus is followed by international instances which provide comparisons and contrasts. With an inquiry approach to learning this is frequently reversed, whereby the investigation of the case studies allows students to 'discover' the concepts of the underlying processes. GIS is particularly suited to this approach, as Tinker (1994) aptly expresses it, tools like GIS allow learning at the edge. Thus a teacher may begin a global issues topic with an investigation of a local or national example. While data may or may not be readily available in digital form, the students may be able to build their own database using digital, geo-referenced base map outlines. As the students begin to understand the relationships and implications involved in the local example, contrasts can be made with similar situations in other countries, by comparing the data. The students can finally attempt to formulate solutions to these issues, as they grapple with the cultural,

STRAND 2—GEOGRAPHY PERSPECTIVE

Standard 2.1 Diversity of People and Places, and Cultures.

Students will describe, compare, and explain the locations and characteristics of places, cultures, and settlements.

- 2.1.1. describe how major world issues and events affect various people, societies, places, and cultures in different ways.
- 2.1.2. explain how culture might affect women's and men's perceptions.

Standard 2.2 Human/Environment Interaction.

Students will describe, compare, and explain the locations and characteristics of ecosystems, resources, human adaption, environmental impact, and interrelationships among them.

- 2.2.1. describe the environmental consequences of major world processes and events.
- 2.2.2. assess the relationship between property ownership and the management of natural resources.

Standard 2.3 Location, Movement, and Connections.

Students will describe, compare and explain the locations and characteristics of economic activities, trade, political activities, migration, information flow, and the interrelationships among them.

- 2.3.1. describe major world patterns of economic activity and explain the reasons for the patterns.
- 2.3.2. explain how events have causes and consequences in different parts of the world.

Standard 2.4 Regions, Patterns, and Processes.

Students will describe, compare, and explain characteristics of ecosystems, states, regions, countries, major world regions, and patterns and explain the processes that created them.

- 2.4.1. explain how major world processes affect different world regions.
- 2.4.2. explain how major world regions are changing.
- 2.4.3. explain how processes like population growth, economic development, urbanization resource use, international trade, global communication, and environmental impact are affecting different world regions.
- 2.4.4. describe major patterns of economic development and political systems and explain some of the factors causing them.

Standard 2.5 Global Issues and Events.

Students will describe, compare and explain the causes, consequences, and geographic context of major global issues and events.

- 2.5.1. explain how geography and major world processes influence major world events.
- 2.5.2. explain the causes and importance of global issues involving cultural stability and change, economic development and international trade, resource use, environmental impact, conflict and cooperation, and explain how they may affect the future.

Figure 8. Michigan High School Geography Content Standards and Benchmarks.

STRAND 5—INQUIRY

Standard 5.1 Information Processing.

Students will acquire information from books, maps, newspapers, data sets, and other sources, organize and present the information in maps, graphs, charts, and timelines, interpret the meaning and significance of information, and use a variety of electronic technologies to assist in accessing and managing information.

- 5.1.1. locate information pertaining to a specific social science topic in-depth using a variety of sources and electronic technologies.
- 5.1.2. use traditional and electronic means to organize and interpret information pertaining to a specific social science topic and prepare it for in-depth presentation.
- 5.1.3. develop generalizations pertaining to a specific social science topic by interpreting information from a variety of sources.

Standard 5.2 Conducting Investigations.

Students will conduct investigations by formulating a clear statement of a question, gathering and organizing information from a variety of sources, analyzing and interpreting information, formulating and testing hypotheses, reporting results both orally and in writing, and making use of appropriate technologies.

- 5.2.1. conduct an investigation prompted by a social science question and compare alternative interpretations of their findings.
- 5.2.2. report the results of their investigation including procedures followed and a rationale for their conclusions.

STRAND 6 - PUBLIC DISCOURSE AND DECISION MAKING

Standard 6.1 Identifying and Analyzing Issues

Students will state an issue clearly as a question of public policy, trace the origins of the issue, analyze various perspectives people bring to the issue, and evaluate possible ways to resolve the issue.

- 6.1.1. generate possible alternative resolutions to public issues and evaluate them using criteria that have been identified.

Standard 6.2 Group Discussion

Students will engage their peers in constructive conversation about matters of public concern by clarifying issues, considering opposing views, applying democratic values, anticipating consequences, and working towards making decisions.

- 6.2.1. engage each other in elaborate conversations that deeply examine public policy issues and help to make reasoned and informed decisions.

Standard 6.3 Persuasive Writing.

Students will compose coherent written essays that express a position on a public issue and justify the position with reasoned arguments.

- 6.3.1. compose extensive elaborated essays expressing and justifying decisions on public policy issues.

Figure 9. Michigan High School Cross-Cutting Content Standards and Benchmarks.

Figure 9—Continued

| |
|---|
| <p>STRAND 7—CITIZEN INVOLVEMENT</p> <p><u>Standard 7.1 Responsible Personal Conduct.</u></p> <p>Students will consider the effects of an individual’s action on other people, how one acts in accordance with the rule of law, and how one acts in a virtuous and ethically responsible way as a member of society.</p> <p>7.1.1. act out of respect for the law and hold others accountable to the same standard.</p> <p>7.1.2. plan and conduct activities intended to advance their views on matters of public policy, report the results of their efforts, and evaluate their effectiveness.</p> |
|---|

Figure 9. Michigan High School Cross-Cutting Content Standards and Benchmarks.

Source: Michigan Department of Education. Michigan Framework for Social Studies Education: Content Standards. Michigan Social Studies Education Project, July 1995.

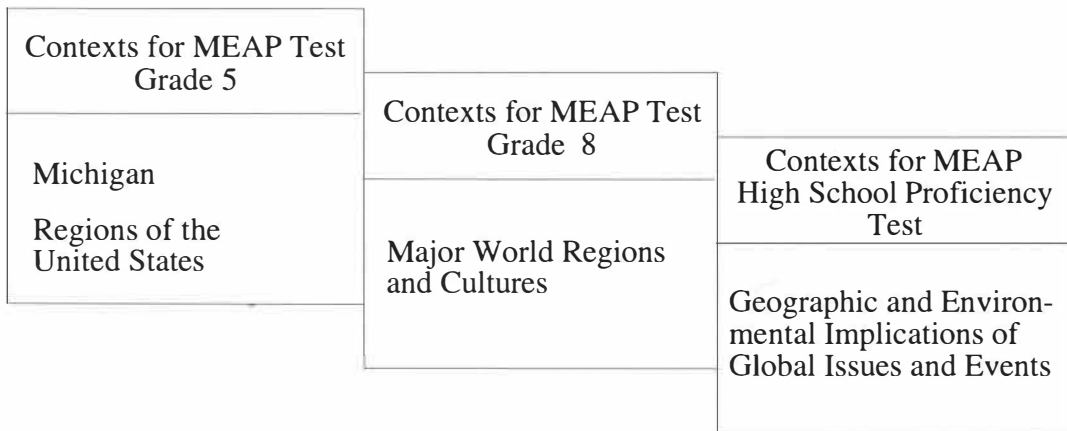


Figure 10. Geography Context for Test Items for the Michigan State Assessment in Social Studies.

Source: Michigan Department of Education. Michigan Framework for Social Studies Education: Plan for Statewide Assessment of Social Studies. Michigan Social Studies Education Project, July 1996.

economic, and regional differences which affect the problem.

For example, pollution is a common topic included in Global Issues courses.

Within this context, in a study of acid rain students could develop different map layers showing the distribution and size of major point sources of sulfur dioxide emissions in the United States; the acidity of rainfall; instances of forest damage (this could be a satellite image showing vegetation distress); and biotically dead lakes and waterways. If groups of students are responsible for developing different data layers this provides an excellent opportunity for collaborative learning. Comparing these data layers with weather and climatic information and elevation data would allow the students to describe patterns, analyze relationships, and develop an understanding of the basic processes and consequences of acid rain and predict which areas are also at risk from this damaging pollutant. This could lead to a discussion on the spatial implications and possible resolution of air pollution problems in North America and the need for international cooperation in developing public policies to control emission of pollutants. Moving this issue to a global scale and still employing a GIS becomes more problematic, as the necessary digital data are more difficult if not impossible to obtain. Indeed finding analog data for other regions of the world can be very tedious. Despite this, some basic mapping on a country or regional scale may be possible, which may be all that is necessary as the process remains largely the same, although the resolution is more complex due to the numbers of countries involved, the cultural perceptions of the issues, and the individual country's financial capabilities to rectify the situation. This could be the principal focus of the latter part of the study. The culmination of this investigation could be a presentation to interested parties or letters to legislators.

In developing a curriculum which uses GIS, it is essential to ensure that it addresses the required context and content standards and benchmarks for geography education in Michigan. In this instance such an investigation into acid rain using GIS fits well into the geography high school context of "Geographic and environmental implications of global issues and events." It fulfills in part four content standards

within the geography perspective, and almost all the cross-cutting content standards, with a total of nine benchmarks, as shown in Table 6.

Could all this be accomplished without using GIS? Indeed, much of it could, as paper maps similar to the data layers could be prepared, but, the analysis of the information would be more difficult and cumbersome using so many maps and tables. The specific GIS features of querying and overlay are ideally suited to investigating a database of this type, allowing student to experiment with ideas as they formulate an understanding. An additional advantage of the GIS is the superior quality of the GIS output which would allow students to swiftly prepare professional quality graphics to accompany presentations or letters to legislators. Finally using the GIS would also allow students to attain mastery of much of the workplace know-how as outlined in the SCANS report for America 2000 (U.S. Department of Labor, 1992) (Table 3).

Other topics which fit within the Michigan Geography context for high schools and which lend themselves to an investigatory approach using GIS as a tool are described in Table 7. Each is referenced to the geography content standards and benchmarks it could help the student achieve. The cross-cutting standards and benchmarks are not cited as almost all the Inquiry benchmarks (Strand 5) will be met in every investigation. The benchmarks from Public Discourse and Decision Making (Strand 6) and Citizen Involvement (Strand 7) which will be addressed will depend upon the questions posed and the methods used in the inquiry.

There are two types of GIS projects which fit particularly well the geography context and content standards, the mapping of global and regional patterns and local case studies. As can be seen from the Table 7 the former is very powerful in satisfying numerous benchmarks. The local case studies on the other hand, while important in understanding underlying principles, address fewer benchmarks. Consequently, it is important to ensure local case studies do not dominate the curriculum and sufficient

Table 6

The Curriculum Requirements Met by an Investigation Into Acid Rain Using GIS

| Bench- mark | Content Standard |
|----------------|---|
| 2.2.1. | describe the environmental consequences of major world processes and events. |
| 2.3.2. | explain how events have causes and consequences in different parts of the world. |
| 2.4.3 | explain how processes like population growth, economic development, urbanization resource use, international trade, global communication, and environmental impact are affecting different world regions. |
| 2.5.2. | explain the causes and importance of global issues involving cultural stability and change, economic development and international trade, resource use, environmental impact, conflict and cooperation, and explain how they may affect the future. |
| 5.1.1. | locate information pertaining to a specific social science topic in-depth using a variety of sources and electronic technologies. |
| 5.1.2. | use traditional and electronic means to organize and interpret information pertaining to a specific social science topic and prepare it for in-depth presentation. |
| 5.1.3. | develop generalizations pertaining to a specific social science topic by interpreting information from a variety of sources. |
| 5.2.1. | conduct an investigation prompted by a social science question and compare alternative interpretations of their findings. |
| 5.2.2. | report the results of their investigation including procedures followed and a rationale for their conclusions. |
| 6.1.1. | generate possible alternative resolutions to public issues and evaluate them using criteria that have been identified. |
| 6.2.1. | engage each other in elaborate conversations that deeply examine public policy issues and help to make reasoned and informed decisions. |
| 6.3.1. | compose extensive elaborated essays expressing and justifying decisions on public policy issues. |

Table 6—Continued

| Bench- mark | Content Standard |
|----------------|---|
| 7.1.2. | plan and conduct activities intended to advance their views on matters of public policy, report the results of their efforts, and evaluate their effectiveness. |

time is given to regional and global comparisons. Care was taken to select projects for which data are probably readily available at least in analog form and which could be performed using a simple GIS program. Not all the projects could be performed on a single piece of software, as some of the investigations are more suited to a raster and others to a vector system. The table demonstrates many global issues can be investigated using GIS as a tool, but most of the projects would be very time consuming as databases would first have to be constructed. It is, therefore, envisaged that only 2 or 3 projects using GIS would be conducted each year. Subsequent classes could utilize these databases more swiftly and could update and revise projects as well as create new ones. In this manner a wealth of digital data will eventually become available to the school, which could be utilized by other disciplines.

Conclusion

GIS technology has exploded onto the business scene in the past decade, generating numerous educational issues which still remain to be fully resolved despite extensive academic discussion. In the newly emerging secondary education GIS field the necessary research questions to address these issues have barely been formulated, however, some fundamental principles are beginning to emerge. Firstly, GIS is most likely to be used as tool within established disciplines rather than as a stand-alone

Table 7

GIS Projects for a Global Issues Curriculum

| Global Issue | GIS Projects | Benchmarks |
|-----------------------------------|---|--|
| <u>Population Dynamics Change</u> | Global mapping of spatial and temporal patterns; comparison with spatial and temporal patterns of GNP and Food Index per capita. | 2.1.1., 2.4.1., 2.4.2., 2.4.3., 2.5.1., 2.5.2. |
| Movement | Mapping of gains and losses due to migration within US; compared to employment statistics. | 2.3.1., 2.3.2., 2.4.2., 2.4.3. |
| | Global mapping of sources of US immigration—changing temporal and spatial patterns. | 2.1.1., 2.3.1., 2.3.2., 2.4.1., 2.4.2., 2.4.3., 2.5.1., 2.5.2. |
| | Case study—impact of refugees by comparison of economic and human welfare statistics for receiving countries. | 2.1.1., 2.3.1., 2.3.2., 2.4.1., 2.4.2., 2.5.2. |
| <u>Human Welfare</u> | Global mapping of indicators of human welfare, e.g., life expectancy, birth rate, infant mortality, disease burden, safe water and sanitation provision, health care provision, PQLI, GNP, literacy, education level. | 2.1.1., 2.4.1., 2.4.2., 2.4.3., 2.5.2. |
| <u>Environmental Hazards</u> | Global mapping of spatial, temporal, and magnitudinal patterns; comparison of damage and injury with population density, economic indicators. | 2.1.1., 2.2.1., 2.4.1., 2.4.3., 2.5.1. |
| Earthquake | Case study—mapping extent of damage with distance from epicenter, population density, and soil type. | 2.2.1., 2.4.1., 2.4.3., 2.5.1. |

Table 7—Continued

| Global Issue | GIS Projects | Benchmarks |
|---|---|--|
| Volcanic eruption Mud slides | Case study—using a DEM and stream function to model zones at high risk from inundation from lava or mud. | 2.2.1., 2.4.1., 2.4.3., 2.5.1. |
| Flood | Case study—mapping of elevation, precipitation, landuse, soils, and population density to model zones of high risk. | 2.2.1., 2.4.1., 2.4.3., 2.5.1. |
| Hurricane/Tornado | Case study—mapping of tracks, magnitudes, and damage; comparison of damage with landuse, population density, economic indicators. | 2.2.1., 2.4.1., 2.4.3., 2.5.1. |
| | Case study—locating shelters, planning evacuation routes. | 2.2.1., 2.3.2. |
| <u>Human Modification of Ecosystems</u> | Global mapping of spatial and temporal patterns of deforestation, agriculture, mining, urbanization, and fisheries, etc. | 2.1.1., 2.2.1., 2.3.1., 2.3.2., 2.4.1., 2.4.2., 2.4.3., 2.4.4., 2.5.2. |
| <u>Environmental Conservation</u> | Case study—comparing landcover with flora and fauna populations spatially and temporally to define criteria for habitat which sustains populations. | 2.2.1., 2.4.3., 2.5.2. |
| | Case study—identification of suitable habitat for reintroduction of species. | 2.2.1., 2.4.3., 2.5.2. |
| | Case study—monitor the health of wetlands over extended time period. | 2.2.1., 2.4.3., 2.5.2. |

Table 7—Continued

| Global Issue | GIS Projects | Benchmarks |
|---|--|--|
| Soil Conservation | Global and regional mapping of soil erosion, meteorological factors, and agricultural practices. | 2.2.1., 2.3.1., 2.3.2., 2.4.1., 2.4.3., 2.5.2. |
| | Case study—mapping of soil type, agricultural practices, and slope, to identify soil erosion potential. | 2.2.1., 2.3.2., 2.4.1., 2.4.3., 2.5.2. |
| <u>Environmental Pollution</u> Water | Case study—regional or local mapping of point and non-point pollution sources compared to water quality of ground and surface waters. | 2.2.1., 2.3.2., 2.4.3., 2.5.2. |
| Air | Case study—regional mapping of air pollution sources, meteorological factors, and areas of pollution damage to establish relationships. | 2.2.1., 2.3.2., 2.4.3., 2.5.2. |
| Land | Case study—mapping of location of brown field sites to predict impact on economic development of community. | 2.2.1., 2.3.2., 2.4.3., 2.5.2. |
| Waste Management. | Case study—determining the optimum location for a local landfill, waste water recovery plant, regional radio-active waste disposal site. | 2.2.1., 2.3.2., 2.4.3., 2.5.2. |
| <u>Economic Development</u> | Global mapping of spatial and temporal patterns of economic indicators. | 2.3.1., 2.3.2., 2.4.1., 2.4.2., 2.4.3., 2.4.4., 2.5.2. |
| Resource Development | Global mapping of resource reserves, production, and consumption. | 2.3.1., 2.3.2., 2.4.2., 2.4.3., 2.5.2. |
| | Case study—determining optimum location for resort (recreational) development. | 2.3.1., 2.4.3., 2.5.2. |

Table 7—Continued

| Global Issue | GIS Projects | Benchmarks |
|--|---|--|
| Industrial Development | Case study—determining the optimum location of an industrial (commercial) facility. | 2.3.1., 2.4.3., 2.5.2. |
| Energy Development | Case study—determining the optimum location for wind (solar, HEP) energy generation. | 2.3.1., 2.4.3., 2.5.2. |
| <u>Urbanization</u> | Global mapping of spatial patterns to compare rate of urbanization with economic indicators and human welfare indicators. | 2.1.1., 2.4.1., 2.4.2., 2.4.3., 2.5.1., 2.5.2. |
| | Case study—determining areas (un)suitable for urban development. | 2.1.1., 2.2.1., 2.5.2. |
| | Case study—modeling plans for urban renewal. | 2.1.1., 2.2.1., 2.5.2. |
| | Case study—modeling of plans for airport noise management. | 2.1.1., 2.2.1., 2.5.2. |
| <u>Trade</u> | Global, regional, and local mapping of spatial and temporal patterns of trading routes and volumes. | 2.3.1., 2.3.2., 2.4.1., 2.4.2., 2.4.3., 2.5.1., 2.5.2. |
| <u>Communications</u> Air, Road, Rail, and Water Transportation, Tele- communications | Global, regional, and local mapping of spatial and temporal patterns of communication routes and usage. | 2.3.1., 2.3.2., 2.4.1., 2.4.2., 2.4.3., 2.5.1., 2.5.2. |
| | Case study—determining optimum route for new highway. | 2.2.1., 2.3.2., 2.4.3. |

curriculum in secondary schools. King (1991) points out, “Geography students need to understand that the major contribution they can make to solving real world problems is in the area of applications of GIS technology, not in the technology itself.” Secondly, the extent of education and training about GIS necessary for its effective use will have to be determined on a trail and error basis at the present time as the research has yet to be conducted. Thirdly, any project which uses GIS will have to match the instructional goals, the discipline’s content standards and benchmarks, and the context of instruction in the curriculum (Woronov, 1994). Finally, despite these constraints there are numerous ways in which GIS can be used in an inquiry approach to learning.

Although there may be compelling cognitive and pedagogical reasons for integrating GIS into the geography curriculum there are numerous practical considerations which have and will continue to impede its widespread acceptance. Some of these issues will be addressed in the subsequent chapters of this research.

CHAPTER IV

A SYSTEMATIC EVALUATION OF SELECTED GEOGRAPHIC INFORMATION SYSTEMS

Introduction

The second part of this research was an evaluation of Geographic Information System software programs. Thorough research revealed there are no GIS programs specifically for pre-collegiate education. Therefore, the K–12 teacher has little option but to purchase a GIS designed for undergraduate education, for research, or a commercial business software package. Faced with this choice, how does the teacher, newly enthused with the potential of using GIS in the classroom, decide which program to use? A review of the literature suggests that IDRISI (an educational and research package from Clark University) and ArcView (a commercial business program from Environmental Systems Research Institute, Inc.) are the most widely used programs. How these selections were made is frequently not described in the literature, although in one instance IDRISI was chosen for “its relatively low cost and low learning curve” (Fazio, 1995). These two programs were also selected for use in two dissertations on GIS in K–12 education. Weller (1993) for her study on “The Appropriateness of GIS Instruction in Grade Six for Teaching Kansas Water Resources” selected IDRISI on the basis of recommendations from a “GIS in Schools” workshop held by The National Center for Geographic Information and Analysis in 1992 and Audet (1993) used ArcView in his work on “Developing a Theoretical Basis for Introducing GISs into High School: Cognitive Implications.” Some vendors are very active in the K–12 arena, e.g., ESRI with their Adopt-a-School program (see

Chapter II).

Software choice may be dependent upon which programs are most readily available, those of which the teacher has most knowledge, or those for which there is available training. Little research was found which could help guide the teacher in this decision-making process. Consequently, in order to elucidate this critical issue further a fourth research question was posed:

4. Which GIS programs are most suitable for use in high school education?

Research Design

The identification of suitable GIS programs was conducted in three stages. The first two stages, the initial selection and a systematic evaluation, are described below and the third, a student evaluation, is detailed in Chapter V.

Initial Selection

There are a large number of GIS programs available. They can be divided into two basic types, those using a vector representation of spatial data and those using a raster form. In the vector model, spatial information is represented using points, lines, and polygons, the position of which are defined by coordinate values. The attributes or information associated with these features are stored in attribute tables. In the raster model, data are represented by a grid, usually of squares, but any tessellating polygon could also be used. Here each cell or pixel carries a single attribute which applies to every location within the cell (Aronoff, 1993). Many programs now incorporate both models, however these tend to be the more expensive packages. Less expensive software often displays both types of data representation but can only analyze one type. Since neither model is inherently superior to the other, as each performs some types of analysis more effectively than the other, it was determined to include both models

amongst the programs selected (Mitchell, 1991).

The initial identification of GIS programs suitable for high school education was approached on the basis of two criteria; cost and ease-of-use. These factors were chosen because of current fiscal constraints on education in Michigan and the limited time allotted to geography within the Michigan curriculum.

Recent changes in the state funding of education in Michigan has led to leaner budgets in many school districts. The local electorate appear less tolerant of millage increases to fund education calling upon school boards to improve efficiency and reprioritize their spending. For example, within the study area of this research, the Gull Lake School District proposed an increase millage in 1996 to finance a much needed upgrade in student computer technologies (Gull Lake Community Schools, 1996). This was rejected by the electorate leading the school board to scale back its plans and seek funds from other areas in the budget. Therefore, in the initial selection procedure a somewhat arbitrary limit of \$500 per student copy was set on the cost of the software. This is probably too high, as state and local fiscal constraints mean there will be little money available to purchase multiple copies of expensive software for use by a single discipline. However, there are very few programs which fall below this limit at present.

The second criterion chosen was ease-of-use, as GIS are notorious for their steep and long learning curves. Inservice teacher training is customarily conducted in short workshop sessions or week-long university courses. Hence, if GIS is to be integrated into social studies classrooms teachers will expect to attain proficiency swiftly. In addition, it is also unlikely the teacher will be able or willing to devote much class time to teaching program operation, because of the wide breadth of the social studies curriculum and the limited time devoted to the discipline in many schools. In the initial selection, any GIS program which followed the Microsoft Windows

interface standard was considered to fulfill the ease-of-use criterion. DOS or menu driven interfaces were thought to lengthen the learning curve too much to make them a practical proposition for introduction into the average high school social studies class. Systems using UNIX were excluded on the basis of the low cost criterion as they are usually prohibitively expensive. As a result, only GIS programs with a Windows interface standard which cost less than \$500 were chosen.

Once this initial selection of GIS programs had been made, basic information on hardware requirements, the data representation, and the methods of data entry were recorded for each GIS. The programs were then subjected to a systematic evaluation.

Systematic Evaluation

Even using a Windows interface standard, there is a considerable difference in the learning curves of programs. Therefore, in order to narrow the choice of programs still further, a methodology was devised to systematically evaluate the ease-of-use of the various GIS. A list was developed of attribute and spatial data functions a GIS could be expected to perform based on those described by Aronoff (1993), Chrisman (1997), and Albrecht (1996) and adapted for use in K-12. It is recognized that all GIS programs do not implement these functions in similar ways. However, they do achieve comparable educational outcomes, which does permit a direct comparison between programs. Further, only those functions which could be performed by all the selected GIS programs were included.

In order to assess how easy these functions were to operate, the number of actions needed to implement each operation was counted. It would also have been possible to use time-to-execute as a means of evaluating ease-of-use. This has a number of advantages, including differentiating between functions which are simple and quick to implement and those which require the same number of actions, but which

are more complex and time consuming. Despite these benefits, it was decided human factors such as variations in familiarity with the software and fatigue, would be too influential on the time taken to execute a function.

In order to allow for the comparison of the results between programs, a strict protocol was established. It was necessary to clearly define the meaning of "a single action". Clicking once on a button or selecting from a menu were both considered a single action since only a single click of the mouse was used, even though the latter took more time. A double click of the mouse was also counted as one action.

All the programs tested made extensive use of dialogue boxes. Some of these could be filled out by typing a line of script or by selecting the appropriate words from scrolling menus. Others required the typing of individual words or the selection of these words from lists and the clicking of buttons on or off. In many cases there were two ways of filling out the same box, typing the command or selecting it from a list or menu. Because of this duplicity of command entry and the difficulty of determining the number of actions involved in typing a line of script, it was decided to describe the filling out of any single dialogue box as one action. Therefore, if a function required the opening and filling out of a dialogue box, two actions were recorded, one to open the box and the second to fill it out. It was recognized this gave an unfair advantage to those programs with complex dialogue boxes. Two other problems arose with dialogue boxes. Firstly in programs which used nested dialogue boxes, the completion of each box was counted as one action. Secondly in most programs closing a dialogue box and executing the function involved clicking on a single button displayed within the box. This was counted as part of the single action of filling out the box. By contrast, in one program the operator had to return to the main program menu and scroll and select the 'execute' command to close the box. It was decided to count this as an extra action because it involved going outside the dialogue box itself.

Not only was the definition of a single action clearly defined, but the same data set was entered into each of the selected GIS to ensure there would be no variations due to differences in the data to be analyzed. Finally, for each GIS function tested one procedure or task was chosen to be carried out with each program. For example, to evaluate the ease-of-use of the attribute editing function, the attribute of one individual areal feature on the landuse map was changed and the number of actions needed to accomplish this task was recorded. The choosing of suitable tasks raised further problems as some functions can be used in several different ways. In these cases it was determined to perform the simplest operation or the one judged most likely to be used in a high school setting.

This systematic evaluation was used to identify the simplest GIS for one function or for a group of functions, or to determine which GIS program was easiest to use overall.

Materials

The data set used in the systematic evaluation was the same one developed for the student software evaluation described in Chapter V. It consisted of six map layers for Thornapple Township in Barry County, Michigan (Table 8). The data files were digital, but they had to be converted into different formats for entry into each of the GIS programs. The file preparation and conversion are described in Appendix A.

Also included in the systematic evaluation for comparison with the computerized GIS was a Manual GIS (Appendix B). It was constructed using the Thornapple data set and its preparation is described in Appendix A.

Table 8
Systematic and Student Evaluation Data Set

| Map Layer | Description and Source Map | Number of Classes |
|-----------|--|-------------------|
| ELEVATION | Elevation (USGS 1:24,000) | 15 |
| LANDUSE | Land cover/use 1994 (Miris, 1978) | 30 |
| LAKES | Lakes (Miris, 1978) | 2 |
| RIVERS | Rivers (Miris, 1978) | 2 |
| ROADS | Country roads (Miris, 1978) | 2 |
| HIGHWAY | Highway M 37: Hastings to Grand Rapids (Miris, 1978) | 2 |

USGS—United States Geological Survey.
Miris—Michigan Resource Information System.

Methodology

Initial Selection

A number of approaches was used to create a list of GIS programs from which to make the initial selection. GIS user and education specialist discussion groups on the Internet were asked which GIS programs they would recommend for high school use. Map II, MapGrafix, MapInfo, and Atlas were some of the programs mentioned by the respondents. A literature search found K–12 more or less dominated by two GIS programs, IDRISI and ArcView, as outlined previously. Trade papers, magazines, promotional materials, and advertisements were also studied to find possible candidates. Public domain software was not considered because of its limited functionality.

The two criteria of ease-of-use and low cost were then used to make the initial selection. Firstly, the cost of a single student copy was determined from promotional materials, from a company's World Wide Web site, or by calling a company's sales department. Only those program costing less than \$500 with an educational discount were included. Secondly, only programs which used the Windows interface standard were retained.

Once a short list had been established, the data representation format of the program and the platforms offered were ascertained. Five programs were selected in which both vector and raster data representation models and PC and Macintosh environments were included. The manufacturing companies for the GIS programs were then approached. Each company either loaned or donated a copy of their software to the Department of Geography at Western Michigan University for use in the study.

Systematic Evaluation

The functions and tasks used in the systematic evaluation are described in Figure 11. Every effort was made to determine whether a program could perform each task, including careful study of the available manuals and on-line help. Non-standard terminology made this task difficult. Each software company's technical support service was used as the final confirmation if a function did not appear to be supported from the printed manual or on-line help service.

The tasks were performed on each of the selected GIS programs. As each task was accomplished the number of actions needed to implement the operation was counted. Each task was repeated at least once to ensure accuracy. The decision rules which were followed are shown in Table 9.

BASIC GIS FUNCTIONS AND TASKS FOR SYSTEMATIC EVALUATION

1. SINGLE MAP MANIPULATION:

- (1) Map Retrieval—displays a map layer.
Task: Display Thornapple Township landuse map.
- (2) Zoom—changes the scale of a display.
Task: Change the scale of landuse map display.
- (3) Find point coordinates—finds the x,y coordinates of one map location.
Task: Find the x,y coordinates of one point/pixel on the landuse map.
- (4) Search by Attribute—searches for selected attributes.
Task: Find all the areas of wetland on the landuse map.
- (5) Classification—classifies spatial features.
Task: Group landuse categories into agricultural, non-agricultural, urban and displaying resultant map.
- (6) Attribute editing—this could involve changing or adding attribute data.
Task: Change the landuse code of one polygon/contiguous zone on the landuse data layer.
- (7) Rescale—changing units of measurement using a mathematical operator.
Task: Convert the elevation data from feet to meters.
- (8) Subset—subsets out a small portion of a map.
Task: Subset the city of Middleville from the landuse map. (If this cannot be done as a rectangle, the appropriate polygons will be selected and clipped.)

2. MEASUREMENT:

- (1) Distance between object pairs—measures distances.
Task: Measure the straight line distance between two points/pixels on a map.
- (2) Area of a polygon
Task: Find the area of one landuse polygon/contiguous zone.
- (3) Perimeter of a polygon
Task: Find the perimeter of one landuse polygon/contiguous zone.

Figure 11. Basic GIS Functions and Tasks Used in Systematic Evaluation.

Figure 11—Continued

3. LOCATIONAL ANALYSIS:

- (1) Visual overlay—overlays different map layers.

Task: Overlay ELEVATION and LAKES map layers.

- (2) Logical overlay—finds where specific conditions from several data layers apply.

Task: Find all the residential areas at elevations of less than 740 feet, as these may be subject to flooding.

- (3) Buffer zone generation—creates a buffer zone of specified width around a point, line, or polygon/zone.

Task: Find all the wetlands within a 500 foot buffer along the Grand Rapids–Hastings highway.

4. DATA OUTPUT:

- (1) Printed output

Task: In each GIS, a map was constructed of Thornapple Township showing the elevation, lakes, rivers, roads, and the highway. It was custom colored and transferred to a layout where a legend, title, and north arrow were added. The Thornapple River was labeled, where possible parallel to the line of flow. The resulting layout was then printed on a color ink-jet printer. This multi-faceted task was also used to evaluate the data output of each GIS.

Figure 11. Basic GIS Functions and Tasks Used in Systematic Evaluation.

Results

Initial Selection

The initial selection of GIS programs resulted in identification of five GIS programs which met the criteria of costing less than \$500 and following the Windows

Table 9
Decision Rules for Systematic Evaluation

| Action | Count |
|--|-------|
| Single or double mouse click. | 1 |
| Opening and selecting an item on drop down menu. | 1 |
| Completion of each dialogue or script box. | 1 |
| If more than one method of completing a task was known, the shortest one was used. | NA |
| All required maps were assumed to be in the appropriate form and displayed on the screen if necessary, before a task was executed. | NA |

NA—Not Applicable

interface standard. Three were vector-based and two raster-based. Details of these programs are shown in Table 10.

The costs quoted are for a single student copy of the software and reflect the reductions which many companies customarily give for educational purposes. Two of the programs, ArcView and MapInfo, are available for both PC and Macintosh environments. As can be seen in Table 10, the minimum hardware requirements vary widely between the five programs. It should be stressed, as each manufacturer does in the documentation, these are very much minimum values. Problems were experienced running all the programs, except Map Factory, on machines with 8 Megabytes (MB) of Random Access Memory (RAM). Some programs ran very slowly, e.g., ArcView, and some were unable to perform certain tasks, e.g., MapInfo and Maptitude. For the purposes of the systematic evaluation, both the PC and the Macintosh machines used

Table 10

General Information on Selected GIS Programs as Determined in 1996

| INFORMATION | PROGRAMS | | | | |
|--------------------------------|-----------------------------------|------------------|-------------------|-----------------------------------|--------------------|
| | ArcView v. 2.1a | IDRISI v. 1.0 | Map Fty v. 1.0 | MapInfo v. 4.0 | Maptitude v.3.0 |
| Cost per single student copy | \$250 | \$248 | \$250 | \$349 | \$395 |
| PLATFORM | | | | | |
| PC | √ | √ | | √ | √ |
| MAC | √ | | √ | √ | |
| Workstation | √ | | | √ | √ |
| HARDWARE REQUIREMENTS minimums | | | | | |
| Hard disk capacity (MB) | 25 ¹ / 13 ² | 10 | 1.1 | 4 ¹ / 4.5 ² | 16 |
| RAM (MB) | 12 ¹ / 8 ² | 4 | 1.5 | 8 ¹ / 4 ² | 8 |
| DATA REPRESENTATION | | | | | |
| Raster only | | | √ | | |
| Raster/display vector | | √ | | | |
| Vector/ display raster | √ | | | √ | √ |
| DATA ENTRY | | | | | |
| Tablet digitizing | | √ | | √ | √ |
| Scanned maps | √ | √ | √ | √ | √ |

Table 10—Continued

| INFORMATION | PROGRAMS | | | | |
|-----------------------|--------------------|------------------|-------------------|-------------------|--------------------|
| | ArcView v. 2.1a | IDRISI v. 1.0 | Map Fty v. 1.0 | MapInfo v. 4.0 | Maptitude v.3.0 |
| Screen digitizing | √ | √ | √ | √ | √ |
| Common data formats | √ ³ | √ | √ | √ | √ |
| REGISTRATION | | | | | |
| By relative position | | √ | | | |
| By absolute position | √ | √ | √ | √ | √ |
| PRINTER COMPATIBILITY | | | | | |
| Ink-jet | √ | √ | √ | √ | √ |
| Laser | √ | √ | √ | √ | √ |
| TUTORIAL | | | | | |
| Hardcopy | √ | √ | √ | √ | √ |
| On-line | √ | | | | |

¹ Macintosh

² PC

³ ArcInfo only

√ Available

MB Megabytes

RAM Random Access Memory

ArcView, Environmental Systems Research Institute Inc., Redlands, CA.

IDRISI, Clark University, Worcester, MA.

Map Fty: Map Factory, ThinkSpace Inc., London, Ontario, Canada.

MapInfo, MapInfo Corp., Troy, NY.

Maptitude, Caliper Corporation, Newton, MA.

were upgraded to 24MB of RAM, after which all the selected programs ran swiftly and well.

The GIS identified reflect both types of data representation, raster and vector. All the programs, except Map Factory which is a purely raster system, could display both types, though none could query and analyze more than one type. One of the most important considerations in GIS selection is data entry. All the programs can import a variety of common data formats, except ArcView which only accepts ArcInfo coverages. IDRISI, MapInfo, and Maptitude support tablet digitizing, while all the programs provide for some screen digitization. To allow for accurate overlay of data layers, the maps should be registered to a coordinate system. In ArcView, the Arc coverages (ArcInfo files) already contain coordinate files. Map Factory, MapInfo, and Maptitude also allow for absolute registration to a number of coordinate systems. IDRISI, while supporting absolute registration, also has the provision for relative registration in which one map layer is registered to another map. This can allow for the correction of some map distortions. Output is very important in an educational setting, since the student will wish to display the fruits of his/her efforts. No program suggested the use of a dot matrix printer. Indeed maps printed by such printers are very unsatisfactory representations of the computer screen graphics. By comparison, ink-jet and laser printers produce accurate and attractive results, particularly in color. The final informational detail collected was on the type and quality of tutorial support with the GIS. All, except ArcView, provided comprehensive tutorials in hardcopy. ArcView's tutorial called Quick Start includes a few very basic instructions on operating the program.

Systematic Evaluation

Four of the programs identified in the initial selection procedure were chosen

for the systematic evaluation. These were: ArcView, IDRISI, Map Factory, and MapInfo. Maptitude was eliminated for a number of reasons. The close similarity of Maptitude and MapInfo would have produced some redundancy if both programs had been included in the evaluation. Maptitude was slightly more expensive and required more RAM than MapInfo to operate successfully. Further, much more difficulty was experienced in data entry and program operation with Maptitude. MapInfo had the added advantage of being available for both PC and Macintosh environments. For these combined reasons MapInfo was chosen for evaluation. ArcView was used on a Macintosh and MapInfo on a PC. IDRISI (PC) and Map Factory (MAC) were platform specific. The PC programs were Windows versions run on Microsoft Windows version 3.1. The Thornapple data set was loaded into each of these software programs.

The four selected computerized GIS and the Manual GIS were systematically evaluated. The number of actions required to complete each of the predetermined tasks was recorded as shown in Table 11. These data were totaled for each of the principal categories of functions. The totals for the four categories are shown in Figure 12.

All the selected programs easily performed the basic single map manipulation operations of map retrieval, zoom, and locating point coordinates. Similarly searching by attribute was universally easy to accomplish, in raster systems with straight forward recoding and in vector systems by query scripts. However, the remaining map manipulation operations were accomplished with varying degrees of difficulty. MapInfo performed all the map manipulation tasks with the fewest actions.

Map measurement is also a common aspect of map processing. The vector programs, because of their data structure, readily provide polygon area and perimeter measurements. This process is more complex in the raster model, particularly with IDRISI. Perimeter measurements were not available in Map Factory. A student armed with a pencil, length of string, ruler, and fine grid overlay could perform each of these

Table 11
Results of the Systematic Evaluation

| TASKS | ArcView | IDRISI | Map Factory | MapInfo | Manual |
|----------------------------|---------|--------|----------------|---------|--------|
| Map retrieval | 1 | 2 | 1 | 2 | 1 |
| Zoom | 2 | 2 | 1 | 2 | NA |
| Find point coordinates | 1 | 1 | 2 | 1 | 2 |
| Search by attribute | 3 | 4 | 3 | 3 | 109 |
| Classification | 14 | 4 | 3 | 4 | 1094 |
| Attribute editing | 8 | 4 | 11 | 3 | 2 |
| Rescale | 6 | 4 | 3 | 2 | 30 |
| Subset | 7 | 6 | 3 | 3 | 35 |
| Map manipulations—Totals | 42 | 27 | 27 | 20 | 1273 |
| Distance btwn object pairs | 2 | 16 | 3 | 3 | 1 |
| Area of polygon | 2 | 10 | 3 | 2 | 3 |
| Perimeter of polygon | 2 | 10 | NA | 2 | 2 |
| Measurement—Totals | 6 | 36 | 6 | 7 | 6 |
| Visual overlay | 1 | 4 | 3 | 2 | 1 |
| Logical overlay | 7 | 8 | 3 | 15 | 51 |
| Buffer zone generation | 6 | 10 | 6 | 14 | 35 |
| Locational analysis—Totals | 14 | 22 | 12 | 31 | 87 |

Table 11—Continued

| TASKS | ArcView | IDRISI | Map Factory | MapInfo | Manual |
|--------------------------|---------|--------|----------------|---------|--------|
| Layout window | 3 | 2 | 1 | 2 | NA |
| Map annotation | 2 | 3 | 2 | 2 | 1 |
| Feature labels | 3 | 15 | 2 | 5 | 1 |
| Color | 4 | 5 | 3 | 5 | 486 |
| Lines styles | 4 | 5 | 3 | 5 | 198 |
| Standard graphic symbols | 2 | 2 | 1 | 3 | 1 |
| Map printing | 2 | 2 | 2 | 2 | NA |
| Data output—Totals | 20 | 34 | 14 | 24 | 687 |
| Totals of all functions | 82 | 119 | 59 | 82 | 2053 |

NA—Not Applicable

tasks on a hardcopy map with relative ease.

Another critical function of GIS is locational analysis. Vector systems perform the visual overlay of two or more map layers most easily, rivaling a manual system. ArcView was especially straight forward requiring a mere click of the mouse and, since alignment is automatic, less time consuming than even a manual system. Raster systems require more thought as coding is important in overlay, sometimes requiring recoding of one or more layers prior to overlay if all map objects are to remain visible and distinguishable. Logical overlay and buffer zone generation functions evaluate the characteristics of the area from more than one data layer and are the investigations in which computers excel. Performing any of these tasks manually is extremely tedious,

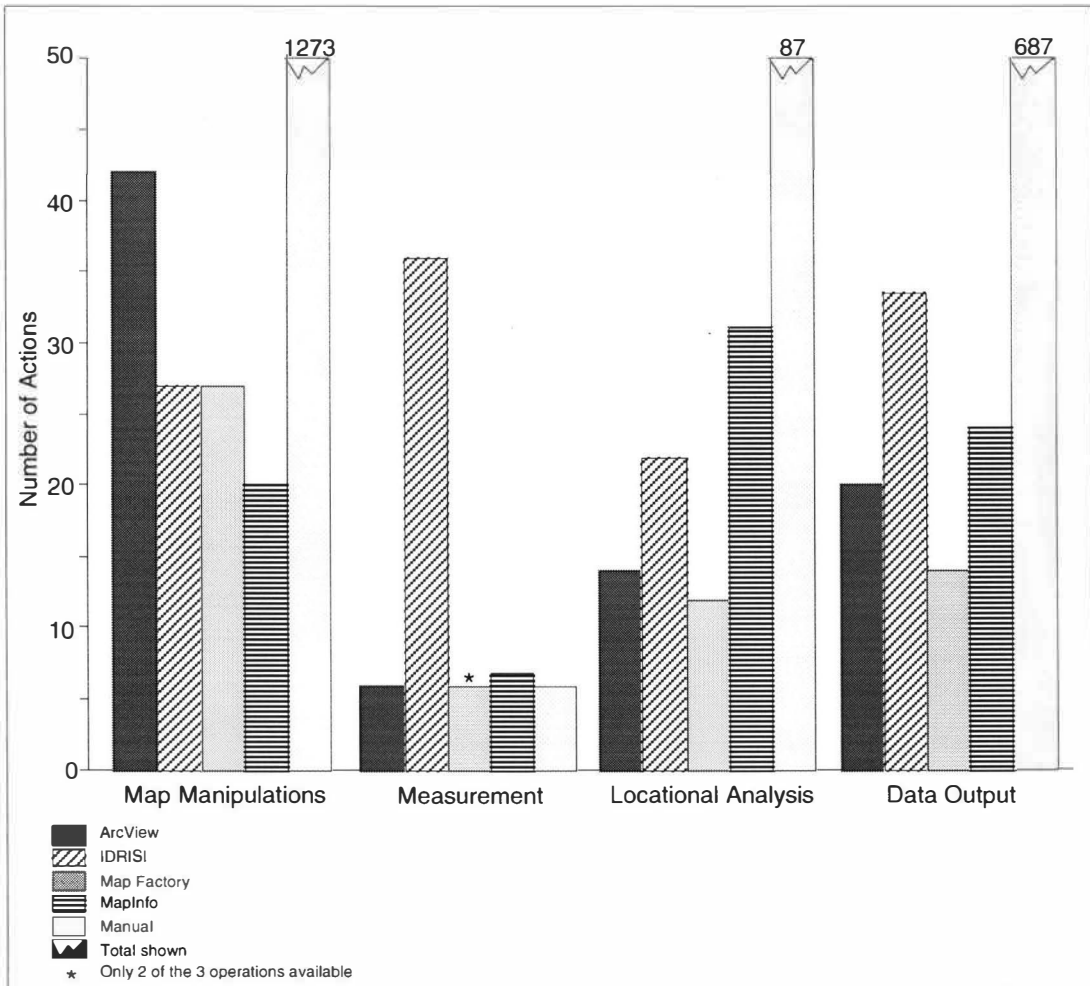


Figure 12. Number of Actions Required to Perform Principal Function Categories.

often unsatisfactory, and certainly of little educational value in relation to time required to complete the exercise. Map Factory performed the three types of locational analysis most easily.

All the computerized GIS have some provision for hardcopy data output. The output performance using color ink-jet printers was compared in this trial. Color inkjet printers are much less expensive than lasers, costing around \$300, and they produced very acceptable results. The output maps are shown in Appendix D. Map Factory

required the fewest actions to produce the specified map.

The GIS programs were ranked from 1 to 5 (with 1 requiring the lowest number of actions) for ease-of-use for these operations. These rankings are shown in Table 12.

Table 12
Ranking of Selected GIS for Ease of Operation on Specified Tasks

| TASKS | ArcView | IDRISI | Map Factory | MapInfo | Manual |
|-------------------|---------|--------|----------------|---------|--------|
| Map manipulations | 4 | 2 | 2 | 1 | 5 |
| Measurement | 1 | 5 | 1 | 4 | 1 |
| Location analysis | 2 | 3 | 1 | 4 | 5 |
| Data output | 2 | 4 | 1 | 3 | 5 |
| Overall Ranking | 2 | 4 | 1 | 2 | 5 |

1 = Easiest to use.

The Manual GIS ranked last in the majority of the group functions. Of the computerized programs Map Factory required fewest actions to complete the prescribed tasks and was deemed the easiest to use.

Discussion

Initial Selection

The two selection criteria of Windows interface standard and low cost swiftly reduced the number of GIS programs under consideration. MapInfo and Maptitude

appeared very similar in mode of operation and in screen appearance. These are both desk-top mapping programs directed at the business market. The third vector-based program, ArcView, had quite different screen graphics and operational interface. It has very limited data entry and analytical procedures, as it was developed primarily as a simple desk-top module to display and manipulate ArcInfo data. All the vector programs can display, but not process raster data. The two raster-based systems selected were originally developed for educational purposes and since they emphasize cartographic modeling provide much greater analytical capabilities. IDRISI is the more sophisticated of the two. Map Factory has a very simple, intuitive interface where refreshingly a map is a map, not a theme or a table or an image! It uses a straight forward scripting language based on Tomlin's map algebra to perform most of the analytical and manipulation functions (Tomlin, 1990). IDRISI, on the other hand, makes extensive use of dialogue boxes, but requires a much greater knowledge of data structure and representation. IDRISI can also display, but not analyze, vector data.

There were considerable variations in documentation provided with the GIS programs. ArcView came with almost no documentation beyond how to install and start the program. A book called Getting to Know ArcView (1996) provides effective documentation for the program. MapInfo and Maptitude had single instructional volumes which included some tutorial materials. Map Factory had three volumes, one of which was entirely devoted to a tutorial. IDRISI also provided extensive documentation and a useful and effective tutorial. Unfortunately, there was no index with IDRISI which was extremely frustrating when searching for a particular function. It is worth bearing in mind that many teachers will not be prepared to spend much time trying to find out how to execute an operation. If a function cannot be easily found, the program will be deemed deficient. It is beholden on the software companies to provide comprehensive and intelligible manuals with indices and effective tutorials particularly

for educational products.

Decisions on software purchase are seldom based on purely educational considerations. Cost and platform availability can bias a choice. GIS is expensive as the programs are complex, but with educational discounts these programs can be affordable. Two of the GIS tested here are available for both Macintosh and PC environments, removing this constraint from the decision equation. However, the computer memory requirements of these programs are considerable and an important consideration in a school setting. A slow running program seriously detracts from the educational value of a GIS. The student must be held on task if educational objectives are to be met and a slow program can only result in at best, frustration and at worst, inattention. Introducing GIS can, therefore, require considerable capital expenditure, if fast, powerful machines are required and are not already available within the school. Only Map Factory could run with as little as 1.5 MB RAM and minimum hard disk capacity of 1.1 MB.

The choice of type of data representation is difficult, as each has distinct advantages and disadvantages. Although no attempt was made in the systematic ease-of-use assessment to compare the results of the specified tasks, there were considerable differences in output. The raster systems could also perform many more types of analysis than the vector systems.

Data entry is always a thorny issue in GIS. The most time consuming and frustrating part of this entire project was data entry. The map layers were already in digital format and merely had to be imported into the selected programs. Unfortunately, the lists of supported file formats in a program's documentation were no guarantee the data would be easy to import. Often "GIS experts" were able to offer little more guidance than to try another method. The alternative is the digitizing of data. Two of the selected GIS, IDRISI and MapInfo, have digitizing modules, as well as

allowing for the scanning and screen digitizing of data. Map Factory and ArcView support the latter method only. Therefore, it is readily apparent that pre-built databases in an appropriate format are an absolute necessity for widespread use of GIS in high schools, since the busy teacher is unlikely to be willing to digitize data except perhaps for small student projects, nor spend many frustrating hours converting data.

Systematic Evaluation

It is important to note at the outset this systematic trial was not intended to be definitive. Many of the tasks, particularly the multi-faceted operations, could be accomplished in several different ways, all producing different action counts. All programs were new to the researcher at the beginning of this project. Therefore, any differences in her ability to use the programs was a direct reflection of the ease-of-use and quality of documentation of the program. An expert in each program could produce different results. Teachers will rarely have the benefit of such expertise. Therefore, the objective of the research was to simulate to some extent a classroom setting, demonstrating what one individual new to a program could realistically accomplish using some GIS knowledge and the documentation provided.

There were fundamental differences in the mode of operation of individual programs. IDRISI tended to require more actions per task because maps are not automatically displayed upon the completion of an operation, as occurs in the other GIS. The display launcher module has to be employed and a dialogue box completed whenever a map is portrayed on screen. For instance, to display a map in custom colors with a legend in IDRISI requires the opening of the dialogue box and the entering of five pieces of information. This was counted as only two actions in this research. By comparison, in ArcView and Map Factory, the same task requires a single click of the mouse. This was counted as one action, but it is obviously more than

twice as fast as the IDRISI procedure. Two other drawbacks with IDRISI are measurement, which was circuitous and tedious, and map data output which has limited flexibility and was difficult to execute.

The second raster-based program, Map Factory, was the simplest to use in 3 of the 4 function groups as well as overall. Map display is simple, requiring a click of the mouse on the map name in the project box. Most functions are executed by typing a script or choosing the words from scrolling menus in a dialogue box. This counted as two actions, but a third action was always incurred, since it was necessary to return to the main menu to execute the operation.

Both vector systems performed some operations very easily, particularly map display and visual overlay, but they have much more limited range of analytical functions. ArcView was ranked first or second in 3 of the 4 function groups. ArcView performed many tasks very easily, while a few required more complex procedures. For example, ArcView has no provision for designating custom categories for choropleth mapping which would permit the rapid visual classification of spatial features.

Finally, MapInfo ranked first in one of the individual function groups and second overall along with ArcView. Many of its functions are performed relatively easily, particularly the single map manipulations. Its analytical capabilities, however, are limited and the execution procedures quite complex.

Although it is clearly impossible to select one program which is easier to use in every function, Map Factory, a raster-based program for the Macintosh was the easiest to use overall. In the vector-based programs both ArcView and MapInfo were equally easy to use overall.

CHAPTER V

A STUDENT EVALUATION OF SELECTED GEOGRAPHIC INFORMATION SYSTEMS

Introduction

The initial selection procedure and systematic evaluation were designed to select the Geographic Information Systems which met the criteria of low cost and ease-of-use, as defined in the previous chapter. However, neither of these methods accommodated personal preference. Each GIS program uses a very different interface, some of which appeared more intuitive and user-friendly than others. Therefore, it was determined to ask high school students to evaluate the selected GIS programs against several criteria. This was the third part of the software evaluation in response to the fourth research question:

4. Which GIS programs are most suitable for use in high school education?

Research Design

In this selection procedure, it was determined to ask students which program they preferred. The Human Subjects Institutional Review Board (HSIRB) of Western Michigan University requires all research projects involving human subjects be submitted for review by the board. Strict regulations govern the writing of the experimental protocols and recruitment of volunteers, particularly of minors. Therefore, the research design for the student evaluation of the software was carefully structured to follow the requirements and recommendations of the Review Board.

The GIS laboratory at Western Michigan University was chosen as the site for

the evaluation because of the special hardware requirements. Students were invited to attend the University on a Saturday morning, so the study would not interfere with their regular schooling. Letters for student assent and parental consent were drafted, along with an explanatory cover letter for parents. These letters and the experimental protocols were submitted to the HSIRB and received approval under the exempt category of review (Appendix E).

Four GIS programs were selected for this evaluation. To ensure an equal representation of the two data models, two raster-based programs and two vector-based programs were chosen. Not all the programs were available for both PC and Macintosh platforms and since some schools favor one platform over the other, it was decided to include both types in the test. Raster and vector programs were selected for both the PC and the Macintosh. The Manual GIS was included to allow for comparison with the electronic forms, since some GIS educators believe this is the most appropriate form of GIS at the K-12 level.

The five GIS programs (four computerized and one manual) were loaded with the same data set. A local data set was chosen so the students would be able to relate more easily to the research questions posed in the evaluation. A geographical concept was chosen for the students to investigate using GIS. This was selected from the geography strand of the Michigan Framework for Social Studies Education (Michigan Department of Education, 1995). Two authentic problems were developed to explore this concept and the students performed the same two problem solving exercises on each of the GIS in turn.

The choice of which spatial analysis procedure to select proved quite difficult, since the GIS vary considerably in the types of analysis they can perform, how difficult they are to execute, and in the results which they produce. There was a conscious effort to select procedures which did not favor one GIS over another in their ease of

operation or the quality of the results. An initial decision to use a polygon within polygon analysis had to be abandoned because the vector-based programs either could not perform the procedure or produced results which were unacceptable. For example, the problem initially proposed was to identify which types of landuse are found within the flood zone of the principal river system as this might impact insurance rates in the area. Two data layers were to be used, one of the landuse and the other of the flood zone. One of the vector-based programs achieved this polygon within polygon analysis by highlighting all the landuse polygons which in some part fell within the flood zone polygon. The landuse layer contained over a thousand polygons, however, most of the land area was cropland which was displayed as one continuous polygon with numerous other landuse polygons within it. In the analysis the cropland polygon was selected, resulting in most of the map appearing highlighted even though the flood zone was quite small. Using an alternative offered by the program to show only those polygons which were completely contained within the flood zone, almost no polygons were highlighted because the flood zone was a narrow feature. Neither result was considered suitable for a study in which students would have limited time to interpret the results.

The two exercises finally chosen involved visual overlay operations and a spatial analysis involving buffer zones. These were selected because they were procedures used frequently in spatial data analysis, ones which each of the programs could perform reasonably well, and which were thought to be most applicable to geography education in the high school setting. Since there would be insufficient time for the students to become proficient users of each program, detailed instructions were written for the individual exercises on each GIS.

At the end of the evaluation the students were given a questionnaire in which they were asked to compare all five GIS. To ensure the students could differentiate

between the programs they tested, they were supplied with the proprietary names and the programs were also color coded and the machines upon which they were operated were marked with an appropriately colored card. The students made extensive use of this color coding system.

Each student evaluation session was restricted to a maximum of 10 students, who worked in groups of two. This limitation was the result of only two Power Macintosh computers being available. It was, therefore, decided to run two sessions in order to increase the sample size to a maximum of twenty. The recruitment of student volunteers was limited to those with computer skills, since the students were required to give their considered opinions on the various GIS programs and it was important their judgment was not influenced by an inability to operate the hardware. In light of this, it was decided to recruit one set of volunteers from the Kalamazoo Area Math and Science Center (KAMSC), a magnet school which draws pupils from 15 area high schools. The KAMSC students are selected by examination and teacher recommendation and attend the school for half of the school day, returning to their area high schools for the rest of the curriculum. The students do not study social studies at KAMSC, but do take those courses in their home schools. They have required computer skills classes in the first two years at the Center. It was recognized these student were not representative of the general student body, but their computer and analytical skills were thought to be beneficial to the project.

The second group was recruited from Loy Norrix High School, one of the two high schools in Kalamazoo. The students here study social studies, but geography is an elective course. The approved experimental protocols and details of the study were submitted to KAMSC and Loy Norrix when the researcher requested permission to make a short presentation and recruit volunteers for the study.

Materials

Two data sets were prepared, one for the demonstration to recruit student volunteers and another for the systematic evaluation and for the student evaluation.

Recruitment Demonstration

A Michigan raster-based data set was prepared for the demonstration. This was chosen because students would be able to more easily relate to problems in their home state. This data set is in the public domain and was available within the Geography Department of Western Michigan University in ERDAS format. Each image is georeferenced to the UTM coordinate system, has cell resolution of 1 kilometer, and a file size of 733 rows and 633 columns containing 4 or 8 bit data. The seven map layers of Michigan selected are described in Table 13.

Three fictitious problem scenarios were selected to demonstrate the use of GIS (Appendix F). The procedures for solving these problems could not be demonstrated in real time as this would take too long. Consequently, maps illustrating various stages of the resultant analysis were prepared using IDRISI. These were imported into ArcView for the Macintosh. ArcView was chosen because of its ease of display and visual overlay. Here, with the judicious use of color and transparent backgrounds, it was possible to visually overlay the map layers to simulate the problem solving process in a matter of minutes, for each of the scenarios. Since no computer display was available at Loy Norrix High School, the maps were transferred to overhead transparencies, for the demonstration.

Table 13
Demonstration Data Set

| Map Layer | Description and Source Map (if known) | Number of Classes |
|-----------|--|-------------------|
| MIBOUND | Boundary outline of State of Michigan | 2 |
| MICOVER | Land cover/use | 10 |
| MIFOREST | Major forest associations (USFS '83) | 9 |
| CTYROADS | County roads (USGS 1:500,000) | 2 |
| WATER | Lakes, rivers, and streams. (USGS Hydro) | 4 |
| ADMIN | Administrative boundaries of national and state parks, recreational areas, and military lands etc. (Michigan State Forest map) | 11 |
| CITIES | Major cities | 2 |

USFS—United States Forest Service.

USGS—United States Geological Survey.

Student Evaluation

Data Set

A local data set was chosen in order to demonstrate to the students that GIS is applicable to their lives and neighborhoods. Unfortunately no data set for Kalamazoo was readily available, therefore, a data set for Thornapple Township in Barry County, approximately thirty miles north northeast of Kalamazoo, was selected. It consisted of six map layers, as shown in Table 8. The preparation of this data set for importation into the four selected computerized GIS is described in Appendix A.

Exercises

Two exercises were developed for student evaluation. The geographical concept chosen for investigation was: Human and Environmental Interaction (Content Standard 2.2, Geography Perspective of Michigan Framework for Social Studies Education). In the first exercise visual overlay was used to explore the way in which the environment affected the rectangular survey system in Thornapple Township. The research question posed was: “How did the environment affect the rectangular survey in Thornapple Township?” The exercise began with an explanation of the concept and of the rectangular survey. Four map layers were used in this exercise; ELEVATION, LAKES, RIVERS, and ROADS. The second exercise involved looking at the concept from the opposite perspective of how people impact the environment. The research question posed was: “Are urban developments encroaching on wetlands in Thornapple Township?” Three map layers were used in this exercise; LANDUSE, ROADS, and HIGHWAY. Spatial analysis utilizing buffer zones and visual overlay were used to address this question. Detailed instructions were developed to guide the students step-by-step through the exercises. Questions were placed throughout the directions to encourage the students to examine the maps carefully at each stage of the analysis. Each set of instructions was designed to be as similar as possible, varying only where operational differences occurred in the software. Five evaluation questions were constructed for inclusion at the end of each set of exercises. These asked what the student liked and disliked about the program’s performance on Exercise 1 and Exercise 2, and how well it defined the results of the analysis. An example of a set of instructions can be found in Appendix G.

Questionnaire

A questionnaire was prepared for the students to complete at the end of the session. It requested general personal details and required the students to rank the five GIS on nine criteria. These criteria were selected as those which high school students may consider important. Finally, three questions were included to discover what the students felt about GIS in general and whether it was the type of software they would like to use in high school (Appendix G).

Methodology

Student Volunteer Recruitment

The first group of volunteers for the student evaluation were recruited from KAMSC. Three presentations were given to the freshman and sophomore classes at the Center, a total of 150 students. The address began with a brief description of GIS and its uses. This was followed by a computerized demonstration of GIS using the Michigan data set (Appendix F). Finally, the student's role in the evaluation of GIS software was carefully explained, as well as the location and date of the study, and the time involved. The procedure for volunteering was then outlined along with the importance of the assent and consent letters. Interested students volunteered to participate by informing their teachers after the presentation and receiving all the necessary documents. Three days prior to the study the completed assent and consent letters were collected from the schools and campus maps and directions given to the student volunteers.

The second group of student volunteers was recruited from Loy Norrix High School. Difficulty was experienced in finding a sufficient number of students willing to volunteer at KAMSC. As a result, it was determined to approach the Honors Society

at Loy Norrix, as this is a group of over fifty students with a strong commitment to community volunteerism. These students were also more representative of the full grade range of the school and could be expected to possess the necessary computer and analytical skills. The researcher was given the opportunity to briefly address this group at the beginning of one of their monthly meetings. The presentation followed the same format as the one use at KAMSC, except the maps were displayed on an overhead projector instead of a computer.

Pilot Student Evaluation Study

The materials for the student evaluation were pilot tested by two freshmen college students. The instructions for conducting the two exercises on each of the individual GIS were found to be accurate and detailed enough for the students to operate the programs largely unaided. The students' principal complaint was that boredom set in when they were confronted with the same questions on each set of directions and they tended to ignore them and hence not study the maps carefully. In light of this, the instructions were redesigned. It was decided the risk of unfairly influencing a student's perception of a program by asking different questions was greatly outweighed by the negative aspects of boredom distracting the student attention from the exercises and evaluation process. Therefore, one set of instructions was constructed for each GIS program containing identical introductions to the concepts, linking and explanatory statements, and questions. These would be used at the beginning of the evaluation session. Then a second set of instructions was developed for each GIS, in which much of the introductory and explanatory materials were removed, except for those referring to the operation of the software. New questions were inserted, such that each set of instructions contained different questions. This resulted in each student starting the evaluation session using identical instructions,

except for variations in operating directions. After which, with each new GIS the student was confronted by different questions and no repetition of ancillary materials. An example of a second set of instructions can be found in Appendix G.

Student Evaluation Study

The two student sessions were conducted in exactly the same manner on different Saturdays. Each session lasted about six hours. The first session consisted of seven KAMSC ninth grade students, the second of nine Loy Norrix eleventh and twelfth grade students.

Two Power Macintoshes, one with 16MB RAM and the other with 24MB Ram, and two Pentium PC computers each with 32MB RAM were used in the study. One selected GIS program was loaded into each of the computers, which was color coded appropriately (Table 14). The Thornapple data set was entered into each program and assembled into the two exercises.

Table 14
GIS Programs and Computer Allocation

| Type of Computer | GIS Program | Color Coding |
|------------------|-------------|--------------|
| Pentium PC | IDRISI | Green |
| Pentium PC | MapInfo | Yellow |
| Power MAC | ArcView | Blue |
| Power MAC | Map Factory | Red |

Each session began with a brief introduction to GIS. In order to explain the differences between raster and vector-based file structures, the students were provided

with a simplified map on which they practiced the different methods of spatial and attribute data encoding (Appendix G). The procedures for the evaluation were carefully explained. The location of the data set was demonstrated on a black and white satellite image of Michigan. The students were then given the questionnaire which they were to fill out upon completion of the session and its contents were explained.

The students were asked to work in pairs and encouraged to rotate between the roles of instruction reader and mouse operator. Since there were an odd number of students in both sessions, one elected to work on her own. This proved unsatisfactory, as without a partner to share the reading of the instructions and debate the answers to the questions progress was slow and errors were more frequently made. Therefore, in each session the student was offered the services of an adult, unversed in GIS, to read the exercises to her, which she accepted. On one of the computer rotations in Session 1, the student worked with another group, as only one program upon which they had not worked was available.

Each group drew lots to determine on which program to begin, since the sequence in which the programs were used may influence student preferences. Students recorded when they began and finished using each GIS, so it would be possible to determine the time spent on each program and the sequence in which they were used. Plans to orchestrate the moves from raster to vector or vice versa proved impractical as students worked at different rates and some programs took longer to run than others. Therefore, once a group finished it moved on to the next available computer. Help on operating the programs was only provided when it was requested. When a group completed the two exercises on a GIS, each student answered five evaluation questions. Upon completion of the entire session, each student individually completed the final questionnaire. Copies of printed data output from each program were made available.

Results

There were three ways in which the students responded during the evaluation. They answered exercise questions, evaluated individual GIS, and comparative ranked the programs. The results will be described within this framework. Owing to the small sample size and the subjective and nominal form of the data collected, statistical analysis of the data was limited to analysis of percentages and proportions in multi-dimensional contingency tables, without reference to differential statistics. With no prior knowledge of the pattern of the relationships between variables, an exploratory technique called Determinacy Analysis v. 3.0 (Chesnokov, 1982, Zaslavsky, 1995, Software available from Context, Ltd., Moscow, 1992) was used to assess the relationships between variables.

Exercise Questions

The questions embedded within each exercise were not designed to measure comparative differences in the learning of geographic concepts with individual GIS and none were detected. The students' ability to analyze the maps they produced did not appear to be affected by which GIS they were using. Nevertheless, from the nature of some of the responses, a universal lack of geographic education was discernible.

Evaluation of Individual GIS

Upon completing work on an individual GIS, the students were asked what they liked and disliked about the way the program performed the visual overlays in Exercise 1 and the analysis in Exercise 2. They were also asked how well the GIS defined the results of the analysis by showing the urban areas which may be endangering wetlands. The student responses are summarized for each GIS.

ArcView

All sixteen (100%) students thought ArcView performed visual overlays easily. Fifty-six percent disliked having to rearrange the Table of Contents to control the order in which the maps are drawn, but 6% liked this feature. Ninety-three percent of the students thought the analysis was easy to perform, though 19% qualified this with comments such as, "I wouldn't have a clue what to do or how to do it without the specific instructions," and "It could be screwed up very easily." Forty-four percent thought the analysis was tedious or there were too many intermediate steps. Thirty-one percent thought ArcView defined the results of the analysis well, while 50% thought the buffer zones should be shown or that only the part of the polygon within the buffer should be highlighted, as one student expressed it "(it) showed all the urban areas affected, not where or by how much." Twelve percent particularly liked the graphics and 6% liked the way the unnecessary areas were deleted from the final map.

IDRISI

Eighty-one percent of the students thought IDRISI performed visual overlays easily, 12% did not like it at all and 69% thought it repetitive, complicated, or time consuming. On the analysis there were very mixed responses, 12% found nothing to like about it, while 25% found nothing to dislike about it as it was effective and "did the job." One student wrote, "I don't know how an independent researcher without step-by-step instructions would fare in the raster/vector environment." Twelve percent liked the Map Composer menu for vector overlay, and 6% liked the way maps were created at each stage, while a further 6% like the fact the steps were repeated and the commands easy to understand. However, 31% thought there were too many dialogue boxes and 6% wanted the maps to automatically display. Sixty-nine percent thought IDRISI

defined the urban areas clearly and concisely, though 19% did not think the graphics were good or thought they were “blobby.” Twelve percent thought the buffer zones should be shown or did not like the fact the buffer zones were twenty feet too narrow because of cell resolution. Other individual positive comments on IDRISI included: “liking the clear images; finding the legend simple to follow; and liking the way the maps opened at a good size.”

Map Factory

In the first Exercise, 56% of the students thought Map Factory performed visual overlays easily, 12% thought “it showed everything neatly and organized,” and 19% liked the way all the maps were visible at each stage. Thirty-one percent disliked the scripts, although 6% thought they were easy to understand, and a further 12% thought the coding was confusing and required a written description. In the analysis 44% thought it performed well, 50% disliked constructing the scripts, 25% did not like having to enlarge each new map, and 12% disliked the initial lack of color. Eighty-seven percent thought Map Factory defined the urban areas well, though 12% disliked the 20 foot inaccuracy caused by the limitation of cell resolution. Other individual comments included: “the white background made the maps clearer; the tool bar was good particularly the numeric magnifying glass; the colors were easy to control; there were too many intermediate steps; and querying is not as clearly defined as with IDRISI.”

MapInfo

Fifty-six percent of the students thought MapInfo performed visual overlays easily, though 37% thought it was tricky. Nineteen percent liked the tool bar, but they did not like having to return to the select tool after using another tool, and 25% liked the

information box. In the analysis, 75% thought MapInfo performed well, they particularly liked being able to see the buffer zones, though 44% thought the analysis was difficult to execute. Sixty-nine percent thought it defined the urban areas well, although 19% recognized some of the polygons were not shown. Individual comments included: “a lack of clarity of the graphics necessitated the repeated use of the zoom function; the terminology is unnecessarily confusing; and the cosmetic layer was somewhat mysterious.” Several students had problems resizing the map window and others lost a map when trying to select it.

Manual

Everyone thought visual overlays were easy with the manual GIS and 31% thought it was easier and took less time than the computer GIS. Even so, 44% had problems aligning the map layers. Sixty-two percent thought the analysis was easy to perform, though 50% were concerned about accuracy, and 62% thought it was too time consuming compared to the computer analysis. Ninety-four percent did not think the manual GIS defined the urban areas well, because of human error, the thickness of the markers, the tendency for the markers to smear, and problems identifying features on the maps. Other individual comments included: “I am in control, not some machine;” “It’s easy to physically touch and move the map;” “it took ...less know how to perform Exercise 1;” “there were no (error-43) complications to worry about;” “You couldn’t experiment with them;” and “(you) have fewer options on how to manipulate data on the maps.”

Comparative Evaluation

In the comparative evaluation, 65 variables were observed for each of the 16 students who participated. These were categorized into four types; personal

information, the time on task, sequence in which the GIS were used, and rankings of the GIS. The students were also asked for their opinions on GIS and its usefulness in the classroom. The results are summarized within this framework.

Personal Information

The students were asked to supply personal information on gender, age, and grade level and to rate themselves on computer expertise (Table 15).

Session 1 consisted of seven 9th grade students, six of whom were 14 and one was 15 years old. They were fairly evenly divided by gender. The students worked in groups of two and only one group was mixed gender. Session 2 contained six 11th and three 12th grade students. Five students were 16 years old, and the remaining four were 17 years old. Seven of the students were male. These students also worked in groups of two and only one group was mixed gender. The majority of the students in Session 1 considered themselves intermediate in computer skills and geographic knowledge. The students in Session 2 were more equally spread between advanced and intermediate, which may be a reflection of their perceived status within their schools.

Time and Sequence

The mean and range of time taken to complete the exercises on each program are shown in Figure 13. The manual GIS appears to be completed more quickly than the others. However, the students were only expected to complete a small portion of the analysis as it was recognized that drawing 500 foot buffer zones to scale around 109 wetlands would be too time consuming for this evaluation (Appendix B). Of the computerized GIS, IDRISI, Map Factory, and MapInfo had mean times of 52 to 53 minutes. ArcView's mean was 7 minutes less. The vector programs showed the

Table 15
Student Evaluation—Personal Information

| Session | Percentage of Students | | | | | | | | | |
|---------------------------|------------------------|--------|----|-------------|----|----|-----|-------|----|----|
| | Male | Gender | | Age (years) | | | | Grade | | |
| | | Female | 14 | 15 | 16 | 17 | 9 | 10 | 11 | 12 |
| Session 1 (7 students) | 43 | 57 | 86 | 14 | | | 100 | | | |
| Session 2 (9 students) | 78 | 22 | | | 56 | 44 | | 67 | 33 | |

| Students' Personal Rating of Their Expertise (%) | | | | | |
|--|--------|----------|-------------------|--------|------------------|
| (16 students) | Expert | Advanced | Inter- mediate | Novice | No experience |
| Using a PC | 12.5 | 19 | 56 | 12.5 | |
| Using a Macintosh | | 12.5 | 75 | 12.5 | |
| Using new software | | 25 | 44 | 25 | 6 |
| Your geographical knowledge | 6 | 50 | 38 | | 6 |

greatest ranges. Of the raster programs IDRISI was the most consistent, taking 50 to 55 minutes to complete in 6 out of 8 of the groups which entered a recording. This was probably due the large number of dialogue boxes IDRISI uses. Group SIG4, which consistently took longer to complete using each computerized GIS, consisted of two males who had difficulty keeping on task. If this group is removed, the maximum time taken on each computerized GIS was remarkably consistent, ranging from 55 to 60 minutes. The minimum times were more varied ranging from 31 to 47 minutes, with

the vector programs being completed the quickest.

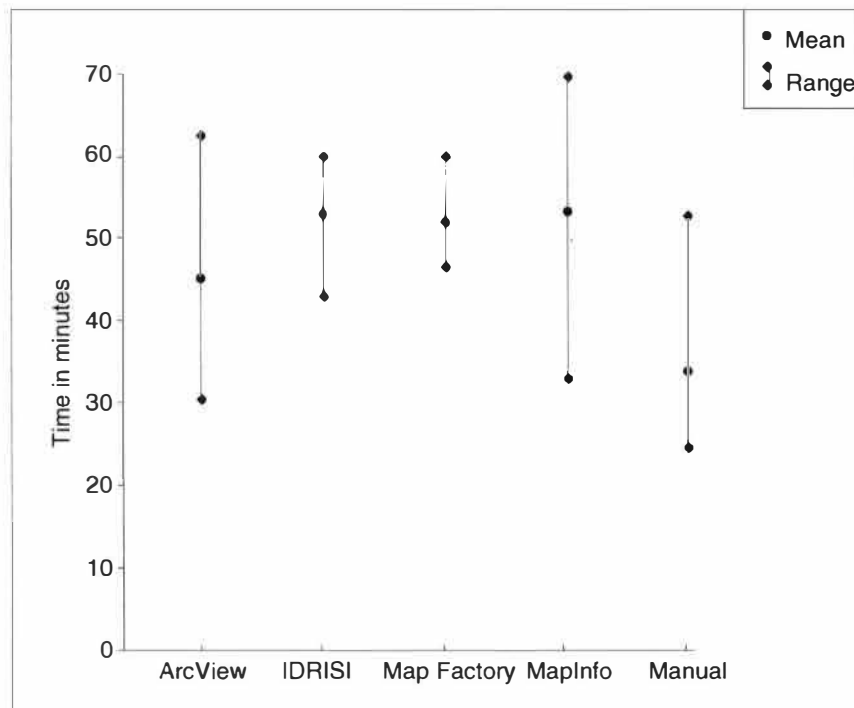


Figure 13. Time Taken to Complete Exercises on Selected GIS.

The time taken to complete the exercises may have been a function not only of the individual GIS, but of the sequence in which they were used (Figure 14). As might be expected students (66%) tended to become more proficient as the session progressed, even though each GIS was different they were becoming more familiar with the exercises and the GIS process. Time may influence ranking, if time spent using a GIS is a measure of its ease-of-use, students may prefer the GIS which performed the quickest. In Figure 14, time is plotted with students' rankings of the GIS they would most like to use again. There appears to be no correlation between time and GIS preference, though this was investigated further using Determinacy Analysis (see page 107).

Sequence may also influence GIS preference. It was postulated that the programs used in the middle of the session may be preferred, because at the beginning of the session students were in a new environment struggling with unfamiliar processes on new hardware and software. By the end of the session, after six hours of repetitive work, tedium may have become a factor. Both these scenarios could influence the student's perception of a program. Although some groups reflected such trends, e.g., S1G2, others did not, e.g., S2G1 (Figure 14). Determinacy Analysis was used to further clarify this relationship (see page 107).

Ranking of GIS

The students were asked to rank the GIS for nine criteria, including performance on each of the two exercises, ease of operation, intuitiveness, quality of screen graphics and hard copy output, most fun to use, and would like to use again (Appendix G). These rankings are summarized in Figure 15.

On Exercise 1 (visual overlay) the students thought ArcView performed the best (56%) and the manual the worst (75%). Eighty-one percent rated Map Factory third or fourth. They were more divided about IDRISI and MapInfo, though they had more positive views about MapInfo (76% ranking it second or third compared to 50% for IDRISI). On Exercise 2 (analysis) the students were in agreement that the manual GIS was the worst (88%), otherwise MapInfo was marginally preferred to ArcView (38% to 31%). The students thought ArcView was the easiest to use (44%) and most intuitive (38%). For quality of screen graphics, Map Factory was the favorite (50%), followed by MapInfo (44%), while MapInfo came out on top for quality of hardcopy (46%). The students did not feel any of the GIS aided their understanding of geographic concepts more than another. MapInfo was considered most fun to use (38%), followed closely by ArcView (31%) and IDRISI (31%). However, the

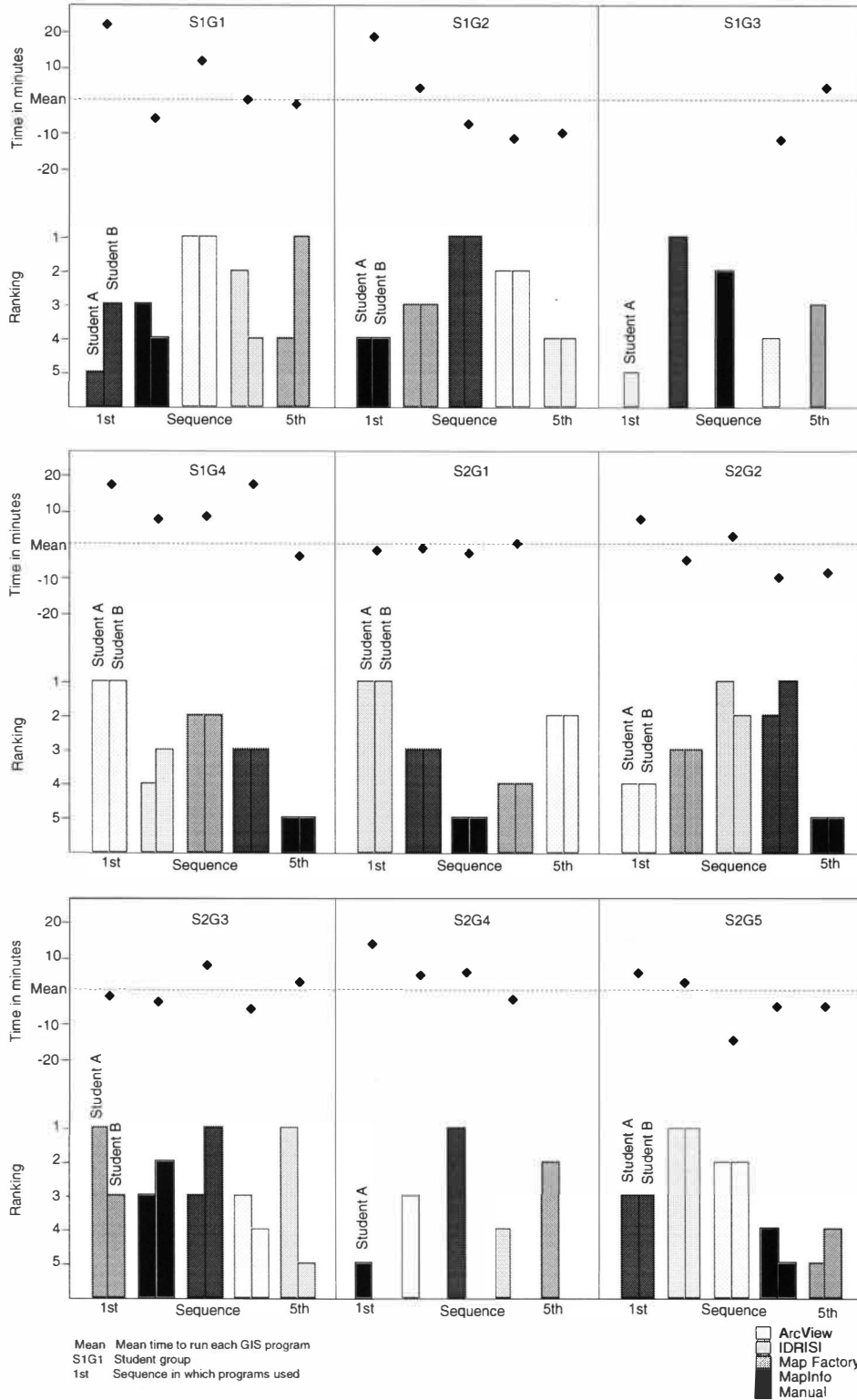


Figure 14. Sequence of Use, Time Taken, and Ranking of Selected GIS by Group.

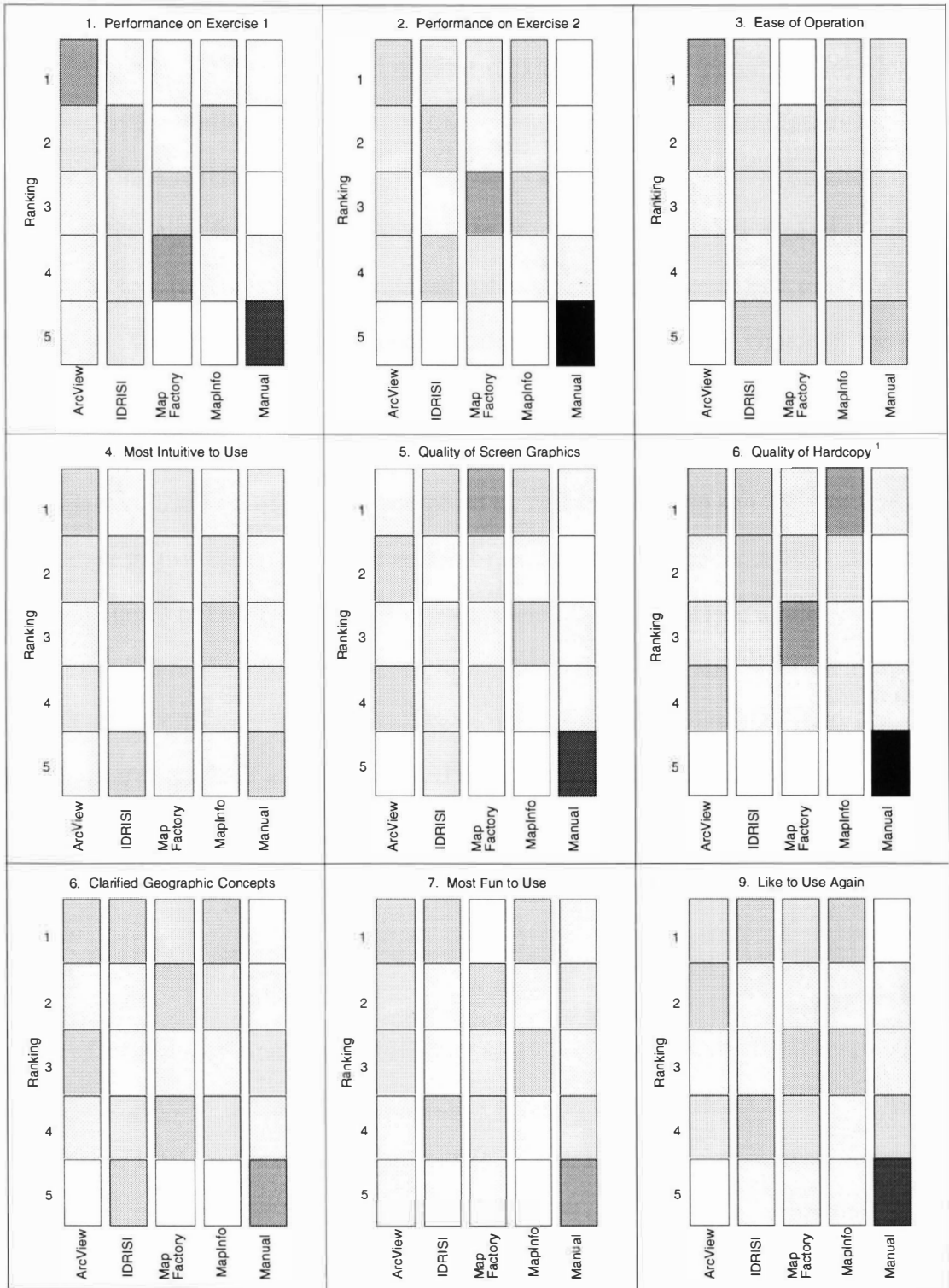


Figure 15. Student Ranking of Selected GIS.

students wished to use IDRISI (38%) and MapInfo (38%) again.

Overall ArcView received 48 first rankings (out of a possible 144) closely followed by MapInfo with 45 (Figure 16), although MapInfo had fewer fourth and fifth place rankings. Students had very varied views about IDRISI, all five rankings were given with similar frequency (range of 23 to 36). Map Factory was repeatedly given middle to low rankings and the manual GIS was frequently relegated to fifth rank (82 /144). Comparing overall incidence of ranking and students' choice of the GIS they would like to use again, the students chose IDRISI and MapInfo equally (38%) as the program they would most like to use again, even though overall in ranking ArcView was selected first 34% of the time compared to 32% for MapInfo and 25% for IDRISI. This suggests that the criteria selected for the evaluation were not equally important in the final choice of GIS preference and that some other factors played a role. A slightly different picture emerges when comparing those GIS programs selected first and second as the GIS they would most like to use again. In this instance ArcView was clearly preferred (63%), followed by IDRISI (50%) and MapInfo (44%). Overall, ArcView received first and second ranking 57%, MapInfo 53%, and IDRISI 45% of the time.

Determinacy Analysis

Determinacy Analysis, a frequency analysis of multi-dimensional contingency tables, was used to investigate relationships between the variables (Chesnokov, 1982, Zaslavsky, 1995, Software available from Context, Ltd., Moscow, 1992). Since the number of subjects was so small, secondary aggregating variables were constructed where possible so more meaningful comparisons could be made. For example, for the variable 'like to use again' it was considered that those students who ranked a GIS first or second liked the GIS and those who ranked it third, fourth, and fifth did not. This

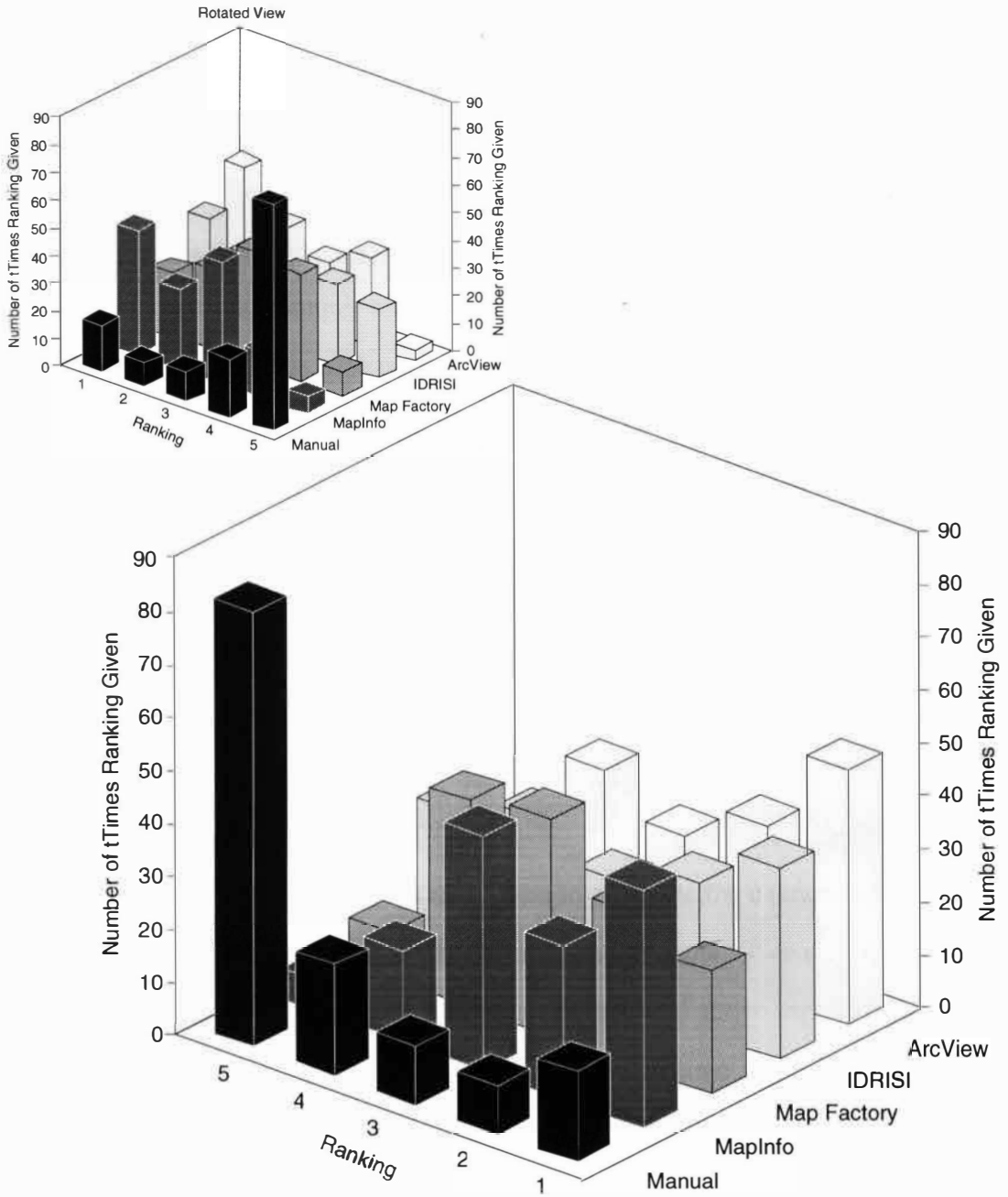


Figure 16. Overall Ranking of Selected GIS.

division was selected since the evaluation was designed to find the best GIS for use in high schools, therefore, any program ranked third or lower would be unlikely to fall into this category. Questions were developed to direct comparisons between the

variables. The analysis is summarized in Table 16.

1. Did older students rank the GIS differently from the younger students? For this analysis the students were grouped by session, since the 14 and 15 year old students were all in Session 1 and the 16 and 17 year olds in Session 2 (Table 17). The younger students preferred ArcView, compared to the older students, 86% to 44% (Figure 17). All the younger students liked its performance (ranked it 1 or 2) on Exercises 1 and 2, whereas 67% of the older students liked its performance on Exercise 1 and only 11% on Exercise 2. Eighty-six percent of the younger students thought ArcView was easy to operate and intuitive compared to 44% of the older students. The reverse seem to be true with IDRISI. Here the older students showed a considerable preference for IDRISI compared to the younger students, 78% to 14%. None of the younger students thought it was easy to operate nor intuitive nor fun to use. With the other GIS the differences were less clear. The younger students marginally preferred Map Factory compared to the older students, 43% to 22%, and thought MapInfo more fun to use, 71% to 33%.

2. Was there a difference in time taken to complete the exercises on each GIS by age? The time data were not available for all the students. Two time designations were used, less than the mean time and the mean time and above for each GIS (Table 18). There was no apparent difference by age in the time taken to complete the exercises on ArcView and IDRISI, although the missing data could upset this balance. In contrast, the older students completed the tasks more quickly than the younger students with Map Factory and MapInfo (67% less than the mean time for older students compared to 29% for younger students). With the Manual GIS, 89% of the older students completed the exercises less than the mean time compared to 57% of the younger students.

Table 16

Summary of Results of Determinacy Analysis

| Question Posed | Yes | No |
|--|-----|----|
| 1. Did older students rank the GIS differently from the younger students? | √ | |
| 2. Was there a difference in time taken to complete the exercises on each GIS by age? | √ | |
| 3. Did the girls rank the GIS differently from the boys? | √ | |
| 4. Was there a difference in time taken to complete the exercises on each GIS by gender? | | √ |
| 5. Did the skilled computer users rank the GIS differently from the unskilled users? | | √ |
| 6. Did the geographically knowledgeable rank the GIS differently from the less geographically knowledgeable? | | √ |
| 7. Did students rank the GIS differently for performance on Ex.1 and Ex.2? | √ | |
| 8. Were some criteria more important to the students when selecting those GIS they would most like to use again? | | √ |
| 9. Were the preferred GIS, the ones upon which the exercises were completed most quickly? | | √ |
| 10. Were the GIS used in the middle of the session preferred to those used early or late in the session? | | √ |

Table 17

Comparison of Students by Age Who Ranked the GIS 1 or 2 for Selected Criteria

| Criteria | Percentage of Students | | | | | | | | | |
|----------------------------|------------------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years |
| Performance on Ex. 1 | 100 ¹ | 67 | 14 | 67 | 14 | 22 | 71 | 33 | 14 | 11 |
| Performance on Ex. 2 | 100 | 11 | 43 | 78 | 14 | 33 | 43 | 78 | 0 | 0 |
| Ease of operation | 86 | 44 | 0 | 67 | 43 | 11 | 43 | 44 | 29 | 33 |
| Most intuitive to use | 86 | 44 | 0 | 56 | 57 | 22 | 43 | 22 | 14 | 56 |
| Quality of screen graphics | 57 | 33 | 14 | 56 | 71 | 67 | 71 | 44 | 29 | 0 |
| Quality of hardcopy | 29 | 33 | 29 | 78 | 14 | 33 | 29 | 78 | 14 | 11 |
| Clarified concepts | 57 | 44 | 14 | 67 | 43 | 89 | 14 | 22 | 57 | 56 |
| Most fun to use | 57 | 56 | 0 | 67 | 71 | 11 | 71 | 33 | 14 | 33 |
| Liked to use again | 86 | 44 | 14 | 78 | 43 | 22 | 43 | 44 | 14 | 11 |

¹ Interpretation - 100% of the students aged 14–15 years ranked ArcView 1 or 2 for performance on Ex. 1. There were 7 students aged 14–15yrs. and 9 students aged 16–17yrs.

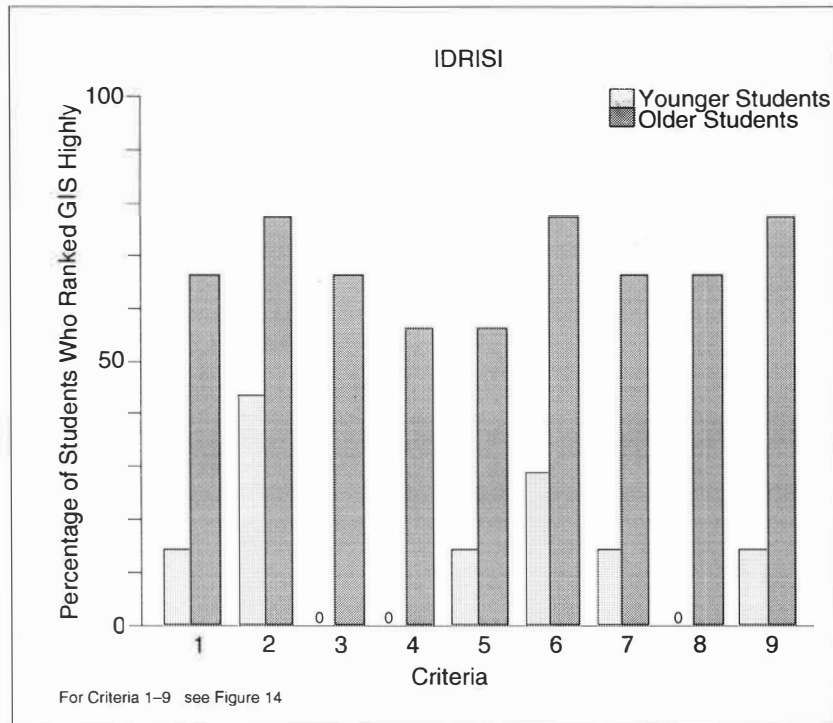
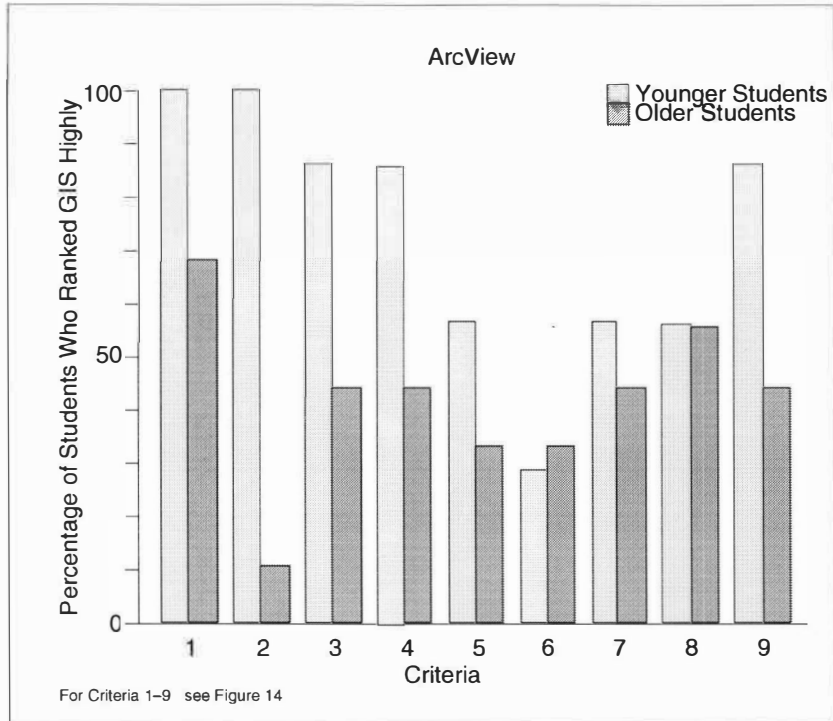


Figure 17. Comparison by Age of Student Rankings of ArcView and IDRISI.

Table 18

Comparison by Age of Time Taken to Complete the Exercises by Students Who Ranked the GIS 1 or 2 for Like to Use Again

| Time | Percentage of Students | | | | | | | | | |
|---------|------------------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years | 14–15 years. | 16–17 years |
| < Mean | 43 ¹ | 44 | 29 | 33 | 29 | 67 | 29 | 67 | 57 | 89 |
| => Mean | 57 | 33 | 57 | 67 | 57 | 22 | 57 | 33 | 29 | 11 |

¹ Interpretation - 43% of the students aged 14–15 years who ranked ArcView 1 or 2 for ‘like to use again’ completed the exercises on ArcView in less than the mean time for ArcView. There were 7 students aged 14–15yrs. and 9 students aged 16–17yrs.

3. Did the girls rank the GIS differently from the boys? Some differences seemed to occur by gender in two programs, IDRISI and MapInfo (Figure 18). The boys preferred IDRISI compared to the girls, 70% to 17%, though the girls (78%) thought it performed better on Exercise 2 than did the boys (43%) (Table 19). However, the girls liked MapInfo more in all respects than the boys, 67% to 30%. Some of the differences observed with IDRISI may be a reflection of age, since the older students also liked IDRISI and the majority of the boys (70%) were older students. The girls' preference for MapInfo cannot be so easily linked to age, since both age groups ranked this program similarly. With ArcView, all the girls thought it performed well on Exercise 1, while only 11% liked its performance on Exercise 2. The boys, on the other hand, thought it performed well on both exercises. Overall there were no other discernible differences by gender on ArcView, Map Factory, and Manual GIS.

4. Was there a difference in time taken to complete the exercises on each GIS by gender? There was no consistent difference in time by gender (Table 20). The girls performed the exercises more quickly than the boys with ArcView (67% of girls to 30% of boys less than the mean) and IDRISI (50% of girls to 20% of boys less than the mean). The boys worked more quickly than the girls with Map Factory (60% to 33%) and the Manual GIS (100% to 33%).

5. Did the skilled computer users rank the GIS differently from the unskilled users? There was no evidence those skilled on the PC or the Macintosh favored the programs using those platforms (Tables 21, and 22). The unskilled computer users also did not appear to favor one platform over another. Neither the students skilled nor those unskilled in using new software showed a marked preference for one program (Table 23).

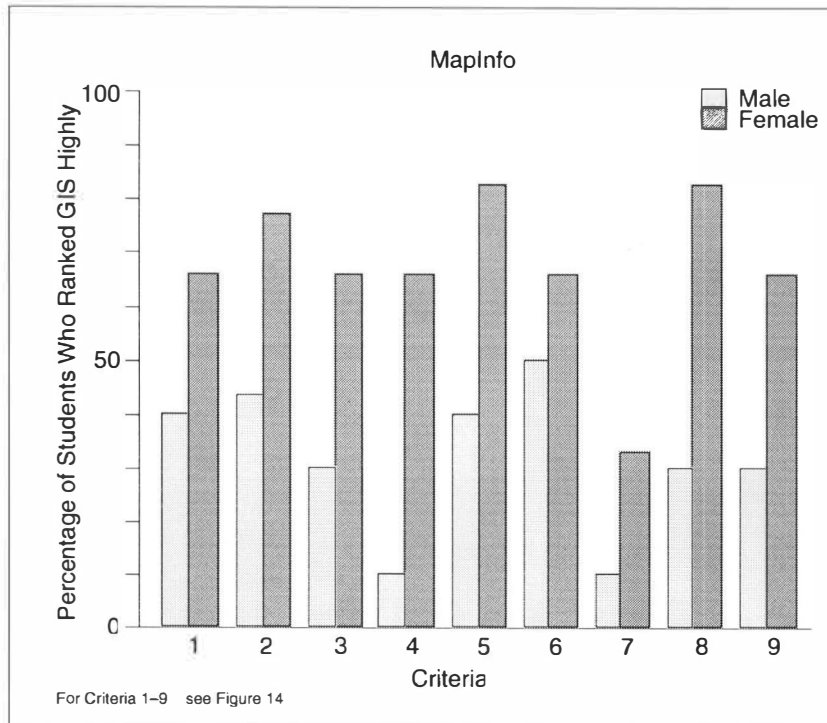
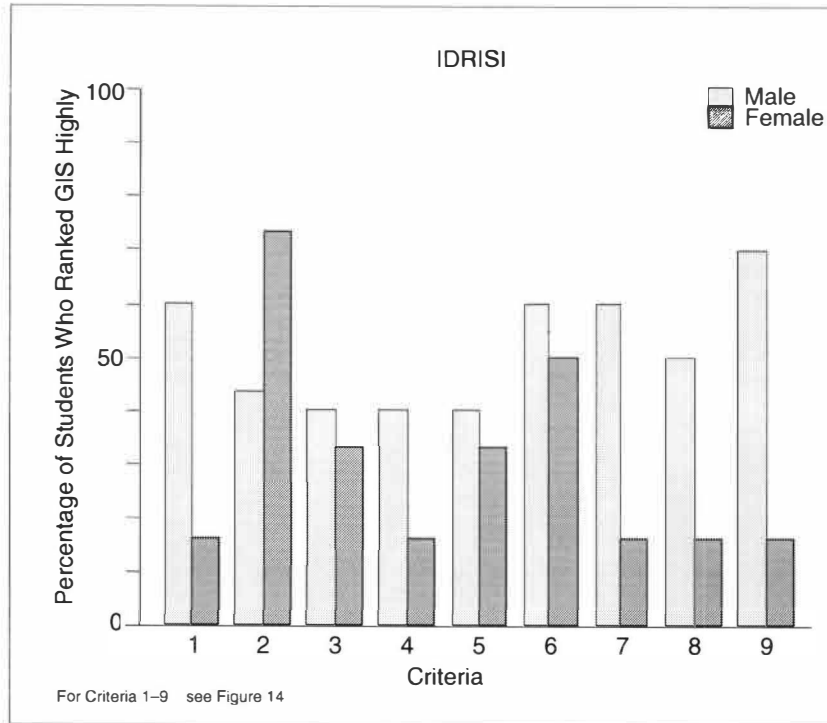


Figure 18. Comparison by Gender of Student Rankings of IDRISI and MapInfo.

Table 19

Comparison of Students by Gender Who Ranked GIS 1 or 2 for Selected Criteria

| Criteria | Percentage of Students | | | | | | | | | |
|----------------------------|------------------------|--------|--------|--------|-------------|--------|---------|--------|--------|--------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| Performance on Ex. 1 | 70 ¹ | 100 | 60 | 17 | 20 | 17 | 40 | 67 | 10 | 17 |
| Performance on Ex. 2 | 100 | 11 | 43 | 78 | 14 | 33 | 43 | 78 | 0 | 0 |
| Ease of operation | 60 | 67 | 40 | 33 | 40 | 0 | 30 | 67 | 30 | 33 |
| Most intuitive to use | 70 | 50 | 40 | 17 | 40 | 33 | 10 | 67 | 40 | 33 |
| Quality of screen graphics | 40 | 50 | 40 | 33 | 80 | 50 | 40 | 83 | 10 | 17 |
| Quality of hardcopy | 40 | 17 | 60 | 50 | 20 | 33 | 50 | 67 | 20 | 0 |
| Clarified concepts | 70 | 17 | 60 | 17 | 60 | 83 | 10 | 33 | 60 | 50 |
| Most fun to use | 60 | 50 | 50 | 17 | 30 | 50 | 30 | 83 | 30 | 17 |
| Liked to use again | 60 | 67 | 70 | 17 | 30 | 33 | 30 | 67 | 10 | 17 |

¹ Interpretation - 70% of the male students ranked ArcView 1 or 2 for performance on Ex. 1. There were 10 male students and 6 female students.

Table 20

Comparison by Gender of Time Taken to Complete Exercises by Students Who Ranked the GIS 1 or 2 for Like to Use Again

| Time | Percentage of Students | | | | | | | | | |
|---------|------------------------|--------|--------|--------|-------------|--------|---------|--------|--------|--------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| < Mean | 30 ¹ | 67 | 20 | 50 | 60 | 33 | 50 | 50 | 100 | 0 |
| => Mean | 50 | 33 | 80 | 33 | 40 | 33 | 50 | 33 | 0 | 50 |

¹ Interpretation - 30% of the male students who completed the exercises in less than the mean time for ArcView ranked ArcView 1 or 2 for 'like to use again'

There were 10 male students and 6 female students.

Table 21

Comparison of Students Skilled and Unskilled in PC Use Who Ranked the GIS 1 or 2 for Selected Criteria

| Criteria | Percentage of Students | | | | | | | | | |
|----------------------------|------------------------|---------|---------|---------|-------------|---------|---------|---------|---------|---------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill |
| Performance on Ex. 1 | 60 ¹ | 91 | 60 | 36 | 20 | 18 | 60 | 45 | 0 | 18 |
| Performance on Ex. 2 | 40 | 55 | 80 | 55 | 20 | 27 | 60 | 64 | 0 | 0 |
| Ease of operation | 60 | 64 | 20 | 45 | 60 | 9 | 20 | 55 | 40 | 27 |
| Most intuitive to use | 40 | 73 | 20 | 36 | 80 | 18 | 20 | 36 | | |
| Quality of screen graphics | 40 | 45 | 60 | 27 | 80 | 64 | 20 | 73 | 0 | 18 |
| Quality of hardcopy | 40 | 27 | 40 | 64 | 40 | 18 | 40 | 64 | 20 | 9 |
| Clarified concepts | 80 | 36 | 60 | 36 | 60 | 73 | 20 | 18 | 60 | 55 |
| Most fun to use | 60 | 55 | 40 | 36 | 40 | 36 | 40 | 55 | 20 | 27 |
| Liked to use again | 60 | 64 | 60 | 45 | 60 | 18 | 20 | 55 | 0 | 18 |

¹ Interpretation - 60% of the students skilled in PC use ranked ArcView 1 or 2 for performance on Ex. 1. There were 11 skilled students and 5 unskilled students.

Table 22

Comparison of Students Skilled and Unskilled in MAC Use Who Ranked the GIS 1 or 2 for Selected Criteria

| Criteria | Percentage of Students | | | | | | | | | |
|----------------------------|------------------------|---------|---------|---------|-------------|---------|---------|---------|---------|---------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill |
| Performance on Ex. 1 | 100 ¹ | 79 | 0 | 50 | 50 | 14 | 0 | 57 | 50 | 7 |
| Performance on Ex. 2 | 0 | 57 | 100 | 57 | 50 | 21 | 50 | 64 | 0 | 0 |
| Ease of operation | 50 | 64 | 50 | 36 | 0 | 29 | 50 | 43 | 50 | 29 |
| Most intuitive to use | 100 | 57 | 50 | 29 | 0 | 43 | 0 | 36 | | |
| Quality of screen graphics | 50 | 43 | 0 | 43 | 100 | 64 | 50 | 57 | 0 | 14 |
| Quality of hardcopy | 0 | 36 | 100 | 50 | 0 | 29 | 100 | 50 | 0 | 14 |
| Clarified concepts | 50 | 50 | 0 | 50 | 100 | 64 | 0 | 21 | 50 | 57 |
| Most fun to use | 50 | 57 | 50 | 36 | 0 | 43 | 50 | 50 | 50 | 21 |
| Liked to use again | 50 | 64 | 50 | 50 | 0 | 36 | 50 | 43 | 50 | 7 |

¹ Interpretation - 100% of the students skilled in MAC use ranked ArcView 1 or 2 for performance on Ex. 1. There were 2 skilled students and 14 unskilled students

Table 23

Comparison of Students Skilled and Unskilled in New Software Use Who Ranked the GIS 1 or 2 for Selected Criteria

| Criteria | Percentage of Students | | | | | | | | | |
|----------------------------|------------------------|---------|---------|---------|-------------|---------|---------|---------|---------|---------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill | Skilled | Unskill |
| Performance on Ex. 1 | 75 ¹ | 83 | 75 | 33 | 0 | 25 | 25 | 58 | 25 | 8 |
| Performance on Ex. 2 | 25 | 58 | 100 | 50 | 25 | 25 | 50 | 67 | 0 | 0 |
| Ease of operation | 75 | 58 | 25 | 42 | 25 | 25 | 25 | 50 | 50 | 25 |
| Most intuitive to use | 75 | 58 | 25 | 33 | 25 | 42 | 25 | 33 | | |
| Quality of screen graphics | 25 | 50 | 25 | 42 | 50 | 75 | 100 | 42 | 25 | 8 |
| Quality of hardcopy | 50 | 25 | 75 | 50 | 0 | 33 | 50 | 58 | 25 | 8 |
| Clarified concepts | 50 | 50 | 75 | 33 | 75 | 67 | 25 | 17 | 50 | 58 |
| Most fun to use | 50 | 58 | 25 | 42 | 25 | 42 | 50 | 50 | 50 | 17 |
| Liked to use again | 50 | 67 | 75 | 42 | 0 | 42 | 50 | 42 | 25 | 8 |

¹ Interpretation - 75% of the students skilled in new software use ranked ArcView 1 or 2 for performance on Ex. 1. There were 4 skilled students and 12 unskilled students

6. Did the geographically knowledgeable rank the GIS differently from the less geographically knowledgeable? The geographically knowledgeable preferred IDRISI compared to the less geographically knowledgeable, 78% to 14% (Table 24). However the less geographically knowledgeable tended to prefer MapInfo, 71% compared to 22% for the geographically knowledgeable. This could be a gender difference, since 70% of boys considered themselves geographically knowledgeable and the boys liked IDRISI, whereas 67% of the girls considered themselves less geographically knowledgeable and girls favored MapInfo.

7. Did students rank the GIS differently for performance on Ex.1 and Ex.2? The students did distinguish between GIS performance on Exercise 1 and 2 (Table 25). They preferred the performance of ArcView (81% ranked it 1 or 2) and MapInfo (50%) on Exercise 1 and IDRISI and MapInfo equally (63%) on Exercise 2.

8. Were some criteria more important to the students when selecting those GIS they would most like to use again? With ArcView of the 63% of students who would like to use it again, 80% liked the way it performed on Exercise 1, they also thought it was easy to operate and intuitive (Table 26). Of the 50% of students who liked IDRISI, 75% thought it performed well on both Exercise 1 and 2 and they found it helpful in understanding geographic concepts. Only 31% of students liked Map Factory, of these 80% thought it intuitive to use and liked the quality of the screen graphics. Eighty-six percent of the proponents of MapInfo, liked its performance on Exercise 1 and thought it easy to operate. Only 12% of students liked the Manual GIS and they all ranked it highly for all criteria except quality of graphics and hardcopy (the map they created). As can be readily seen there were no criteria which the students as a group consistently perceived as important in evaluating the individual GIS programs (Figure 19).

Table 24

Comparison of Geographically Knowledgeable Students and the Less Geographically Knowledgeable Who Ranked the GIS 1 or 2 for Selected Criteria

| Criteria | Percentage of Students | | | | | | | | | |
|----------------------------|------------------------|-------|--------|-------|-------------|-------|---------|-------|--------|-------|
| | ArcView | | IDRISI | | Map Factory | | MapInfo | | Manual | |
| | Kn. | Unkn. | Kn. | Unkn. | Kn. | Unkn. | Kn. | Unkn. | Kn. | Unkn. |
| Performance on Ex. 1 | 78 ¹ | 86 | 67 | 14 | 33 | 0 | 11 | 100 | 11 | 14 |
| Performance on Ex. 2 | 33 | 71 | 78 | 43 | 33 | 14 | 56 | 71 | 0 | 0 |
| Ease of operation | 67 | 57 | 44 | 29 | 22 | 29 | 22 | 71 | 44 | 14 |
| Most intuitive to use | 67 | 57 | 44 | 14 | 44 | 29 | 11 | 57 | 33 | 43 |
| Quality of screen graphics | 22 | 71 | 44 | 29 | 78 | 57 | 56 | 57 | 11 | 14 |
| Quality of hardcopy | 44 | 14 | 67 | 43 | 33 | 14 | 67 | 43 | 22 | 0 |
| Clarified concepts | 67 | 29 | 67 | 14 | 67 | 71 | 11 | 29 | 67 | 43 |
| Most fun to use | 67 | 43 | 58 | 14 | 33 | 43 | 33 | 71 | 22 | 29 |
| Liked to use again | 67 | 57 | 78 | 14 | 22 | 43 | 22 | 71 | 11 | 14 |

¹ Interpretation - 78% of the geographically knowledgeable students ranked ArcView 1 or 2 for performance on Ex. 1.
Kn. - Geographically knowledgeable, 9 students. Unkn. - Geographically less knowledgeable, 7 students.

Table 25

Comparison of Students Who Ranked the GIS 1 or 2 for Performance on Exercise 1 and 2

| Criteria | Percentage of Students | | | | |
|----------------------|------------------------|--------|-------------|---------|--------|
| | ArcView | IDRISI | Map Factory | MapInfo | Manual |
| Performance on Ex. 1 | 81 ¹ | 43 | 19 | 50 | 12 |
| Performance on Ex. 2 | 50 | 63 | 25 | 63 | 0 |

¹ Interpretation - 81% of the students ranked ArcView 1 or 2 for performance on Ex. 1.

Table 26

Students Who Ranked Criteria 1 or 2 for the GIS Which They Would Like to Use Again

| Criteria | Percentage of Students | | | | |
|----------------------------|-------------------------------------|-----------------------------------|--|------------------------------------|-----------------------------------|
| | ArcView 10 students ¹ | IDRISI 8 students ¹ | Map Factory 5 students ¹ | MapInfo 7 students ¹ | Manual 2 students ¹ |
| Performance on Ex. 1 | 100 ² | 88 | 40 | 86 | 100 |
| Performance on Ex. 2 | 70 | 88 | 60 | 75 | 100 |
| Ease of operation | 90 | 62 | 60 | 86 | 100 |
| Most intuitive to use | 90 | 62 | 80 | 71 | 100 |
| Quality of screen graphics | 50 | 63 | 80 | 86 | 50 |
| Quality of hardcopy | 20 | 63 | 40 | 57 | 0 |
| Clarified concepts | 60 | 88 | 40 | 43 | 100 |
| Most fun to use | 80 | 75 | 60 | 86 | 100 |

¹ Number of students who ranked the GIS 1 or 2 for 'like to use again'.

² Interpretation - 100% of the students who would like to use ArcView again ranked ArcView 1 or 2 for performance on Ex. 1.

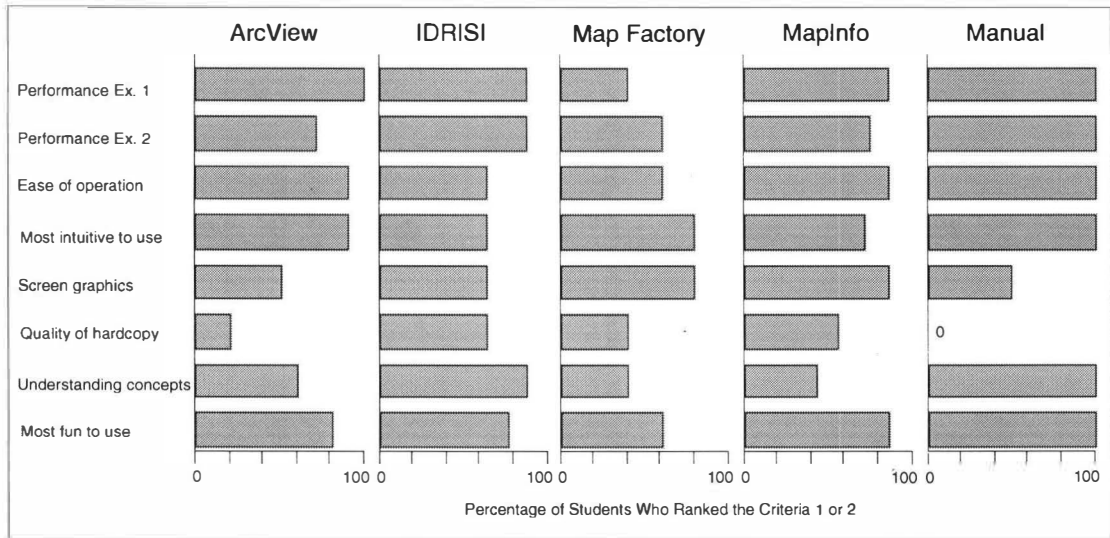


Figure 19. Percentage of Students Who Ranked Individual Criteria 1 or 2 on the GIS They Would Most Like to Use Again..

9. Were the preferred GIS, the ones upon which the exercises were completed most quickly? Preference for a GIS did not seem to be dependent on the time taken to complete the exercises (Table 27).

10. Were the GIS used in the middle of the session preferred to those used early or late in the session? It is important to point out that the sample size in this comparison is very small. No more than four students could use a program at any one time, that is two in each session. However, students do appear to prefer the GIS they used third, apart from the Manual (Table 28). Nevertheless most of the students did not necessarily dislike the programs they used first or last, which might be expected if unfamiliarity and boredom were the sole deciding factors in their choice.

Student Opinions

The students were asked if they wanted GIS software to be available in their high school classroom. All of them concurred, however, 19% qualified this by saying

Table 27

Comparison of Time Taken to Complete Exercises by Students Who Rank the GIS 1 or 2 for Like to Use Again

| Time | Percentage of Students | | | | |
|---------|-------------------------------------|-----------------------------------|--|------------------------------------|-----------------------------------|
| | ArcView 10 students ¹ | IDRISI 8 students ¹ | Map Factory 5 students ¹ | MapInfo 7 students ¹ | Manual 2 students ¹ |
| < Mean | 57 ² | 40 | 50 | 25 | 50 |
| => Mean | 57 | 60 | 29 | 33 | 0 |

¹ Number of students who ranked the GIS 1 or 2 for 'like to use again'.

² Interpretation - 57% of the students who completed the exercises in less than the mean time for ArcView ranked ArcView 1 or 2 for 'like to use again'.

Table 28

Students' Ranking the GIS for Like to Use Again and the Sequence in Which They Used the GIS

| Programs | Percentage of Students | | | | | | | | | | | | | | | | | | | |
|-------------|----------------------------------|---------|-----------|---------|--------------|--------|-----------|---------|-------------|---------|-----------|--|--------------|--|-----------|--|-------------|--|-----------|--|
| | First Liked | | Not Liked | | Second Liked | | Not Liked | | Third Liked | | Not Liked | | Fourth Liked | | Not Liked | | Fifth Liked | | Not Liked | |
| ArcView | 50 ¹ (2) ² | 50 (2) | 0 (0) | 100 (1) | 100 (4) | 0 (0) | 40 (2) | 60 (3) | 100 (2) | 0 (0) | | | | | | | | | | |
| IDRISI | 67 (2) | 33 (1) | 50 (2) | 50 (2) | 100 (2) | 0 (0) | 33 (1) | 67 (2) | 25 (1) | 75 (3) | | | | | | | | | | |
| Map Factory | 50 (1) | 50 (1) | 0 (0) | 100 (4) | 100 (2) | 0 (0) | 0 (0) | 100 (2) | 33 (2) | 67 (4) | | | | | | | | | | |
| MapInfo | 0 (0) | 100 (4) | 33 (1) | 67 (2) | 80 (4) | 20 (1) | 50 (2) | 50 (2) | 0 (0) | 0 (0) | | | | | | | | | | |
| Manual | 0 (0) | 100 (3) | 25 (1) | 75 (3) | 33 (1) | 67 (2) | 0 (0) | 100 (2) | 0 (0) | 100 (4) | | | | | | | | | | |

¹ Interpretation - 50% of the students who used ArcView first ranked ArcView 1 or 2 for 'like to use again'.

² Number of students.

they personally did not have classes to which it was applicable and a further 19% wanted GIS software providing it was not IDRISI.

In response to the question of why they would find GIS useful in school, the students thought the computerized GIS was easier, quicker, more fun, more accurate, and a source of more data than the Manual version. Being faster, it was suggested, a computerized GIS would provide more time for experimentation, being fun it would stimulate more people to learn and keep them interested. GIS would also provide additional computer skills. One student thought it provided a better understanding of geography and another said it helped her to see the relationships between land features, drainage, and urban areas.

In the final open comment section, students said GIS was fun, interesting, and useful. Some expressed concern that the software was difficult to learn and impractical for their schools, which could not even afford pencils. Four students declared MapInfo was the best, another that with a few modifications ArcView was definitely superior, and two liked IDRISI for educational purposes, particularly its interface.

Discussion

In the evaluation of individual GIS the students generally found the programs operated satisfactorily. Only with IDRISI did some students express adamant dislike, nevertheless, there were others who liked it. One student declared a bias toward raster-based programs, though the majority showed a preference towards the vector-based GIS. The researcher also experienced frustration with many of the idiosyncrasies of individual programs identified by the students.

In ArcView no buffer zones are shown in the analysis and since all the polygons which intersect with the buffer are selected, it is not possible to determine the extent of the buffer zone within these polygons (Figure 20). MapInfo does show the

buffer, a fact appreciated by the students. Despite this, only the polygons whose centroid falls within the buffer are selected, which results in some of the larger urban areas not being shown as possibly endangering wetlands (Figure 21). The quality of MapInfo's graphics and the difficulty in enlarging the maps to fill the screen necessitated the repeated use of the zoom function. The maps also tend to be skittish, occasionally vanishing from the window. In the raster-based programs visual overlay is a more complex procedure than in vector programs. However in the analysis, raster software can show which urban areas fall in the buffer, within the limitations of cell resolution (Figures 22 and 23). Strong opinions were engendered by IDRISI. The number and complexity of the dialogue boxes is a disadvantage, as is the absence of automatic map display. The students liked Map Factory's graphics and some of the easy-to-operate functions, but they did not like the scripting language, nor the small sized, gray-tone intermediate maps. Visual overlay with the Manual GIS was of course very easy, but the students soon discovered the problems in using it to conduct an analysis. They almost all assumed that the computer rendered maps were more accurate than the ones they constructed, and as far as line width and measurement consistency are concerned this is probably true. This attitude highlights the need for education about GIS and data accuracy if students are to effectively utilize this tool.

When the students ranked the GIS programs at the end of the session several inconsistencies emerged. Having declared visual overlay was very easy using the Manual GIS, 75% of the students ranked it fifth on visual overlay performance. The majority consistently ranked the Manual GIS low for all criteria, except 'ease of operation' and 'most intuitive to use'. However, even here 31% and 38% still ranked the Manual fifth for these criteria respectively. This probably reflects these students' preference for computer technologies, with which they were proficient. Other students without such computer savvy may have preferred the Manual GIS, for as two students

ArcView

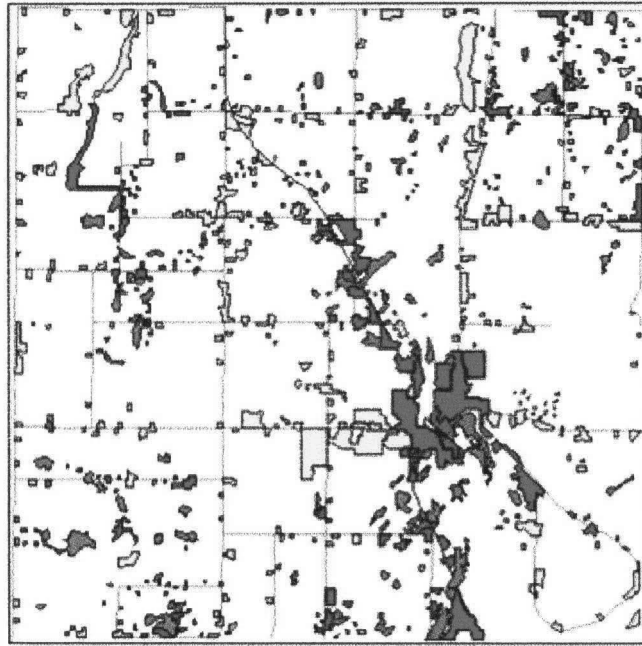


Figure 20. ArcView—Results of Spatial Analysis.

MapInfo

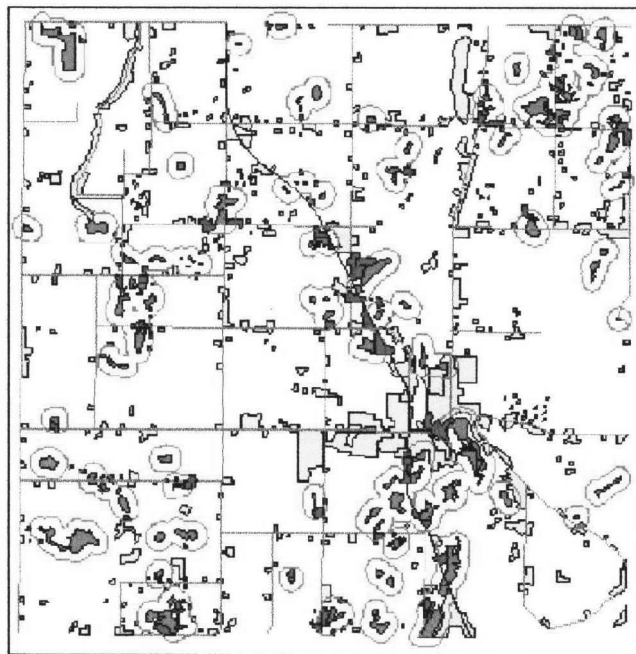


Figure 21. MapInfo—Results of Spatial Analysis.

IDRISI

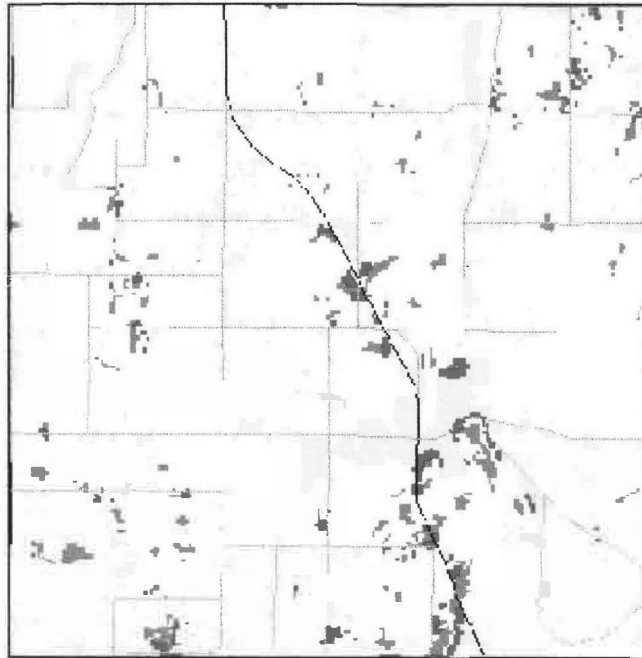


Figure 22. IDRISI—Results of Spatial Analysis.

Map Factory

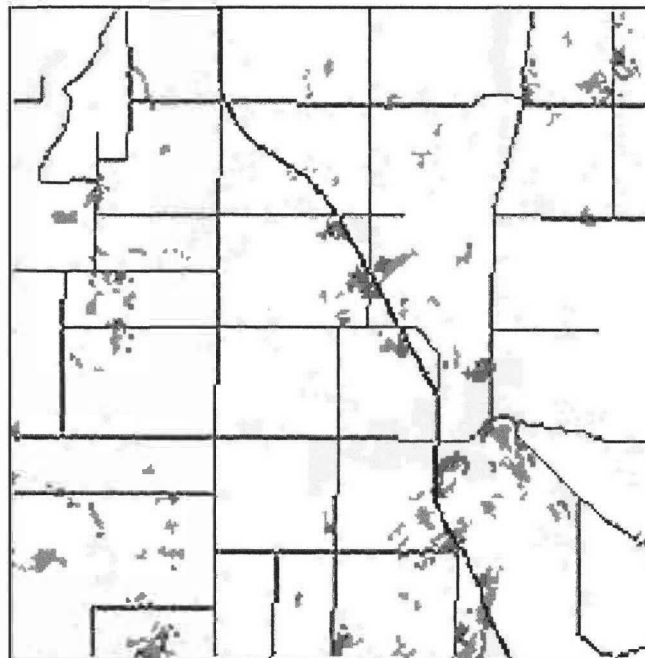


Figure 23. Map Factory—Results of Spatial Analysis.

expressed it “..it is nice to have all the materials in front of you,” and “..it is ... more tangible.” On the ‘quality of screen graphics’ students were told to use the quality of the transparencies and paper maps of the Manual GIS in the comparison. The Manual GIS was identical to ArcView, from which it was created. Even so, 75% ranked the Manual GIS fifth, whereas 100% ranked ArcView between first and fourth. This again further illustrates the students preference for computer technologies.

In five out of the nine groups, the students tended to provide similar rankings to their partner, although they were asked to fill out the questionnaires individually. This was probably inevitable, since they had worked with the programs together, experienced the same frustrations and exhilarations, and discussed the method and results in detail. It is also possibly a reflection of the importance to teenagers of group membership and cohesion.

The time taken and sequence of use appeared to have no significant influence on GIS program preference. As might be expected, the older students executed the exercises marginally faster on some of the GIS programs.

Age and gender seemed to be the most influential variables for GIS preference. In this particular study it is difficult to separate the two, because of the manner in which the genders were distributed in the two age groups. For example, with the preference for IDRISI by the older male students, age appears to be the more important variable, since the younger boys tended to rank IDRISI low. With the older girls it is less clear as the girl who was working alone disliked IDRISI, whereas the other, who was working with a boy, liked it. A female gender preference for MapInfo was more pronounced, as only on one occasion did a girl rank MapInfo below third, compared to 20 occasions with the boys.

Despite the six hours in which the students were involved in this evaluation, the students appeared to enjoy using computerized GIS, and found it interesting and

exciting. Cries of “cool!” would often accompany a new map flashing onto the screen. When we looked at a false color satellite image of SW Michigan in the lunch break they demonstrated they had learnt quite a lot about the geography of Thornapple Township, identifying the steep forested slopes on the eastern margins of the township and the Thornapple River valley which bisects the area.

No single selected criterion appeared to be deemed by the students to be of critical importance in their choice of the GIS they would most like to use again. This suggests some other factor(s) is playing a role in the final preference choice, or the students are weighing a combination of individual qualities of the GIS in making their selection. Since some students had very strong views against IDRISI, MapInfo and ArcView would appear to be the most widely favored GIS programs for high school use by the students in this sample.

CHAPTER VI

THE TECHNOLOGICAL STATUS OF HIGH SCHOOLS WITHIN THE STUDY AREA

Introduction

The third part of this research was an evaluation of the computer technology currently available in high schools in the study area. This is an important issue at a period of reduced state funding for schools and failing bond and millage proposals as communities force school districts to become more efficient and to rethink priorities. For Geographic Information Systems to become widespread in pre-collegiate education at this time, it has to be easy and economical to implement. This view posed a further four research questions:

5. Do high schools within the study area have the necessary hardware to operate GIS programs or would new computers have to be purchased?
6. Do social studies classes have access to computers?
7. Do schools with larger student enrollment have a lower student/computer ratio than schools with a smaller student enrollment?
8. Does the rural or urban nature of the communities from which a school draws its students affect the student/computer ratio?

Research Design

In order to address these research questions, it was decided to develop a questionnaire to be sent to each of the high schools in the study area. The format was designed to be as simple as possible so as to encourage the maximum response. It was

further decided to send the questionnaire to the computer teachers at each school, since they were thought to be most likely to know the technical details of the school's machines. The names of these teachers were ascertained by calling each school, so that the questionnaires could be personally addressed, to further encourage the maximum response. A cover letter briefly explaining the purpose of the questionnaire was enclosed. To determine if high schools had computers capable of running GIS programs, questions on numbers, type, and memory capacities of the school's student computers were assembled in tabular form. The second question, concerning access of social studies students to these computers, was approached by adding two questions to the questionnaire, each requiring the circling of a "Yes" or "No" answer (Appendix H).

Two additional items of information about each school were sought. These were the approximate student enrollment of the school and whether the school served a rural or urban community. Both these factors were considered to be instrumental in influencing the technological status of individual schools. It was hypothesized that urban schools with their large size and more affluent tax base may have a lower student/computer ratio and more powerful machines than smaller rural schools. The designation of a community as urban or rural was based on census data for 1990.

Materials

Since GIS are principally concerned with the manipulation of spatial graphics, they usually require large amounts of Random Access Memory (RAM) to run even basic functions. Program and data storage are also very demanding of hard disk capacity. Therefore, the manufacturer's suggested minimum and recommended hardware requirements for each GIS program selected for study were obtained to provide base levels with which to compare the computing capabilities of school computers (Chapter IV).

The minimum hardware requirements of the GIS programs examined in this study were determined from publications provided by the manufacturer, their sales departments or from their World Wide Web sites. These are shown in Table 29.

Table 29
Minimum Hardware Requirements for Selected GIS

| GIS Program | Memory (RAM) MB ¹ | Program Storage MB | Processor/ Operating System |
|-------------------|---------------------------------|-----------------------|--------------------------------|
| ArcView (PC) | 8.0 + 17.0 (VM) ² | 13.0 | 80386/Win 3.1 |
| ArcView (MAC) | 12.0 + (+VM) | 25.0 | Power/68040/ Mac OS 7.1 |
| IDRISI (PC) | 4.0 | 10.0 | 80386/Win. 3.1 |
| Map Factory (MAC) | 1.5–2.0 | 1.1 | 680x0/Mac OS 7.0 |
| MapInfo (PC) | 4.0 | 4.5 | Win. 3.1 |
| MapInfo (MAC) | 8.0 | 4.0 | Power/Mac OS 7.1 |
| Maptitude (PC) | 8.0 | 16.0 | 80486/Win. 3.1 |

MB¹—Megabytes

VM²—Virtual Memory

Table 29 illustrates the wide variation in program storage requirements (1.1 to 25.0 megabytes {MB}) and memory requirements (1.5 to 12.0 MB) between the programs. Most manufacturers recommend much higher values than the minimums for smooth running of the programs. For instance, ArcView suggest 32 MB of RAM (12.0 MB minimum) for the MAC version and IDRISI 8 MB or more (4.0 MB minimum). The manufacturers also advise the use of sophisticated operating systems. These recommended hardware requirements are shown in Table 30.

Table 30

Recommended Hardware Requirements for Selected GIS

| | Memory (RAM) MB ¹ | Program and Data Storage MB | Processor/ Operating System |
|-------------------|---------------------------------|--------------------------------|--------------------------------|
| ArcView (PC) | 12.0 +17.0 (VM) ² | 38.0 | 80486/Win 3.1 |
| ArcView (MAC) | 32.0 | 45.0 | Power/Mac OS 7.5 |
| IDRISI (PC) | >8.0 | 12.0 | 80486/Win. 3.1 |
| Map Factory (MAC) | 8.0 | 4 .0 | 680x0/Mac OS 7.0 |
| MapInfo (PC) | 8.0 | 12.0 | Win. 3.1 |
| MapInfo (MAC) | 16.0 | 16.0 | Power/ Mac OS >7.1 |
| Mapitude (PC) | 12.0 | 16.0 | 80486/Win 3.1 |

MB¹—Megabytes

VM²—Virtual Memory

Information on the approximate student enrollment of each school was obtained from the Intermediate School Districts where possible, or from the individual schools. The most recent data available for all schools were for the 1994–1995 school year. This was also the year for which the schools' technological data were collected. Census data for 1990 were studied for the communities served by these high schools in order to determine if they were largely rural or urban communities. The Census reports total population for each 'designated place' and 'parts of place' and the percentages of that population which are considered urban and rural. Thus data were available for townships, villages, and cities.

Methodology

Once the questionnaires were returned, the data contained were collated into a single table (Appendix H). The minimum hardware requirements of each of the selected GIS was compared with technical data supplied by each school. This process was repeated for the recommended hardware requirement of each GIS.

Information on the approximate enrollment of each school was compared to the number of student computers available and the capacity of those computers.

The 1990 census data were aggregated for each township, see Figure 24. As can be seen, most school districts do not encompass entire townships, but often parts of several townships. Therefore, it was necessary to estimate whether a school district was largely urban or rural using these data. For example, if the estimated population of the school district was described by the Census as over 50% urban, then the school district was designated as urban. It was recognized, however, that this environmental designation did not reflect the true status of the school population. This could only be determined by completing an individual student enumeration, which was beyond the scope and requirements of this study. Since it was impossible to determine an environmental status for schools which were known to draw students from more than one school district, such as the parochial schools, an “undesigned” category was created. The environmental data were related to the student/computer ratio and computer capacity in each school. The school enrollment and environmental data are shown in Appendix H.

Results

Of the thirty-seven high schools which received questionnaires, nineteen responded (51%) (Figure 25). Of these respondent schools, 11% had only Macintosh

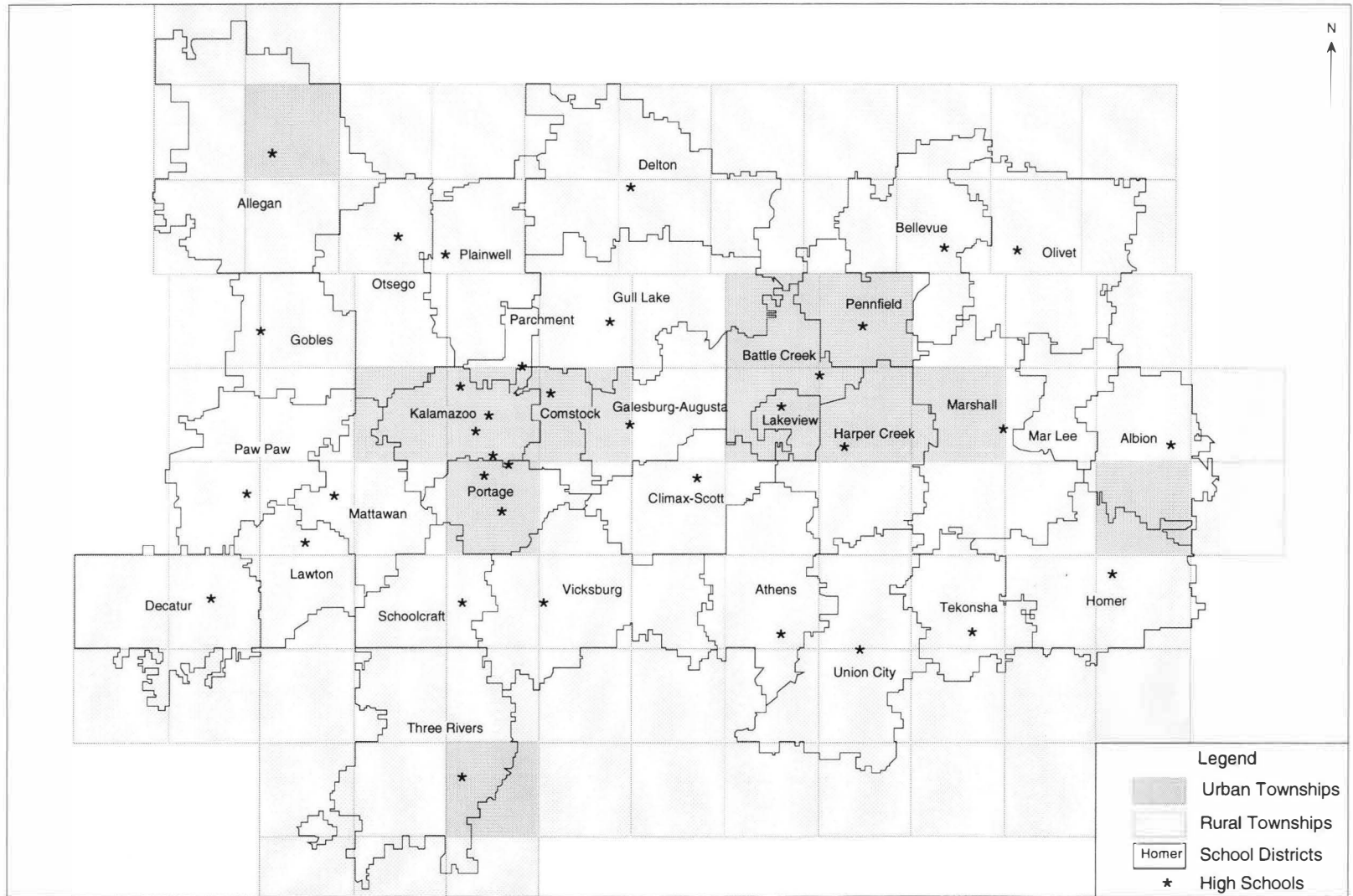


Figure 24. Rural and Urban Townships in the Study Area.



Figure 25. High Schools From Which Responses Were Received.

computers, 63% had only PC computers, 21% had both Macintosh and PC computers, and 5% had Apple computers. Of those schools having PC computers, 25% stated they had the Microsoft Windows interface standard operating system. All the GIS in this study which use the PC platform, were Windows versions. None of the GIS which use the Macintosh platform would operate on an Apple computer.

The minimum and recommended hardware requirements for each of the selected GIS software packages were compared with the technological data provided by each school. The schools which possessed at least some computers which met these minimum and recommended requirement are recorded in Table 31.

Table 31
Schools With Computers Which Met Software Requirements

| School | Enrollment | Environment | # Students/ Computer | # Programs Min. Levels | # Programs Rec. Levels |
|--------------------|------------|-------------|-------------------------|---------------------------|---------------------------|
| Delton Kellogg | 567 | Rural | 5.2 | 5 | 2 |
| Harper Creek | 816 | Rural | 32.6 | 1 | 0 |
| Loy Norrix | 1292 | Urban | 14.7 | 1 | 1 |
| Portage Central | 1133 | Urban | 7.8 | 2 | 1 |
| Hackett | 486 | Undesignate | 32.4 | 1 | 1 |
| KAMSC | 150 | Undesignate | 2.5 | 3 | 0 |

Min.—Minimum hardware requirement

Rec.—Recommended hardware requirement

As might be expected, for each GIS program there were more schools with computers which met the minimum hardware requirements than the recommended requirements. Thirty-two percent of the respondent schools could operate at least one type of GIS software at minimum hardware levels, 21% of these schools could also operate at least one type of GIS at recommended levels. Unfortunately, in only 21% of the schools are these computers available to social studies classes. In one other school, (KAMSC), no social studies is taught, nevertheless the computers would be available to any class which choose to use GIS software, such as earth science which is taught as an elective in the eleventh and twelfth grades.

The number of schools which could operate each GIS program at minimum and recommended hardware levels is shown in Table 32.

Table 32

Number of Schools With Computers Which Met Software Requirements

| | Minimum | Recommended |
|-------------------|---------|-------------|
| ArcView (PC) | 1 | 0 |
| ArcView (MAC) | 0 | 0 |
| IDRISI (PC) | 2 | 1 |
| Map Factory (MAC) | 5 | 2 |
| MapInfo (PC) | 3 | 2 |
| MapInfo (MAC) | 1 | 0 |
| Maptitude (PC) | 1 | 0 |

All the GIS programs except the Macintosh version of ArcView could be operated at minimum hardware levels in at least one school. Nevertheless, only

IDRISI, Map Factory, and the PC version of MapInfo could be operated at recommended hardware levels. No school had Macintosh computers which could operate ArcView at the minimum or recommended levels.

Student enrollment data were then compared to the numbers of student computers in each school, see Figure 26.

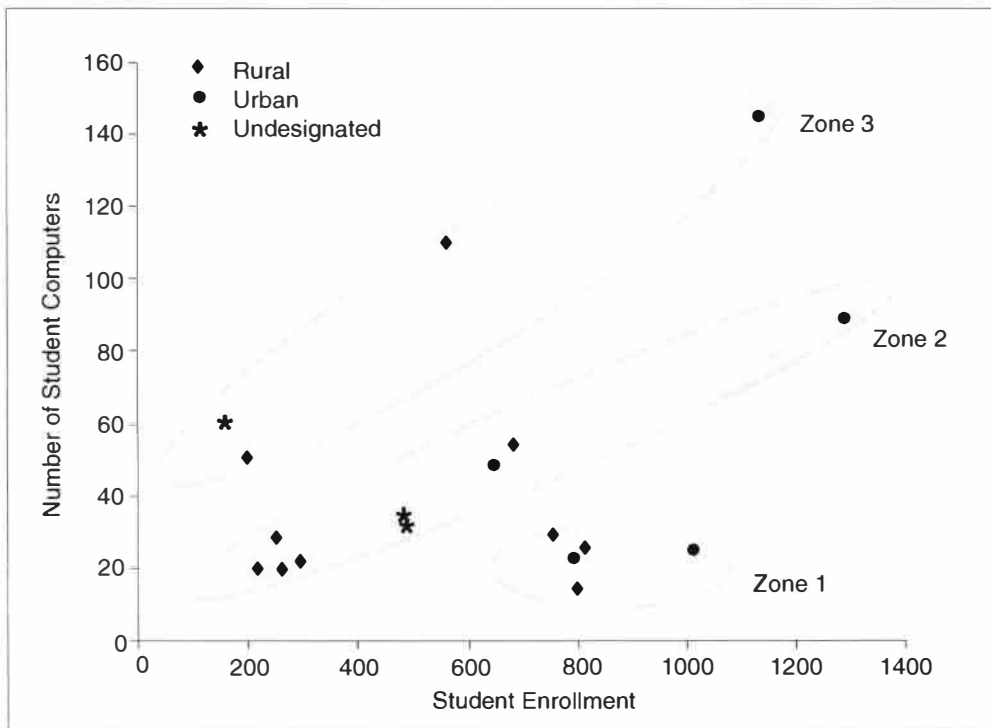


Figure 26. Relationship Between the Number of Student Computers and School Enrollment and Environmental Designation.

In this scattergram the schools appear to fall into three zones. In Zone 1 were medium to large sized schools with enrollments of 747 to 1006 students. These schools usually had one computer laboratory of 12 to 28 machines, giving an average student/computer ratio of 40:1. Zone 2 had a wide range of school sizes (216 to 1292 students) which had an average student/computer ratio of 13:1. The third zone also showed a variety of student population sizes (150 to 1133) with an average

student/computer ratio of 5:1. Schools representing urban and rural environmental designation categories were found in each zone. Undesignated schools were found only in Zones 2 and 3. Figure 27 demonstrates more directly the relationship between the environmental category and the student/computer ratio and the resultant three average student/computer ratio zones identified in Figure 26. For instance, 50% of the rural schools have an average student/computer ratio of 13:1, compared to 40% of the urban and 66% of the undesignated schools. Nevertheless, these effects appear very marginal and it is probable that in this study area school size and environmental

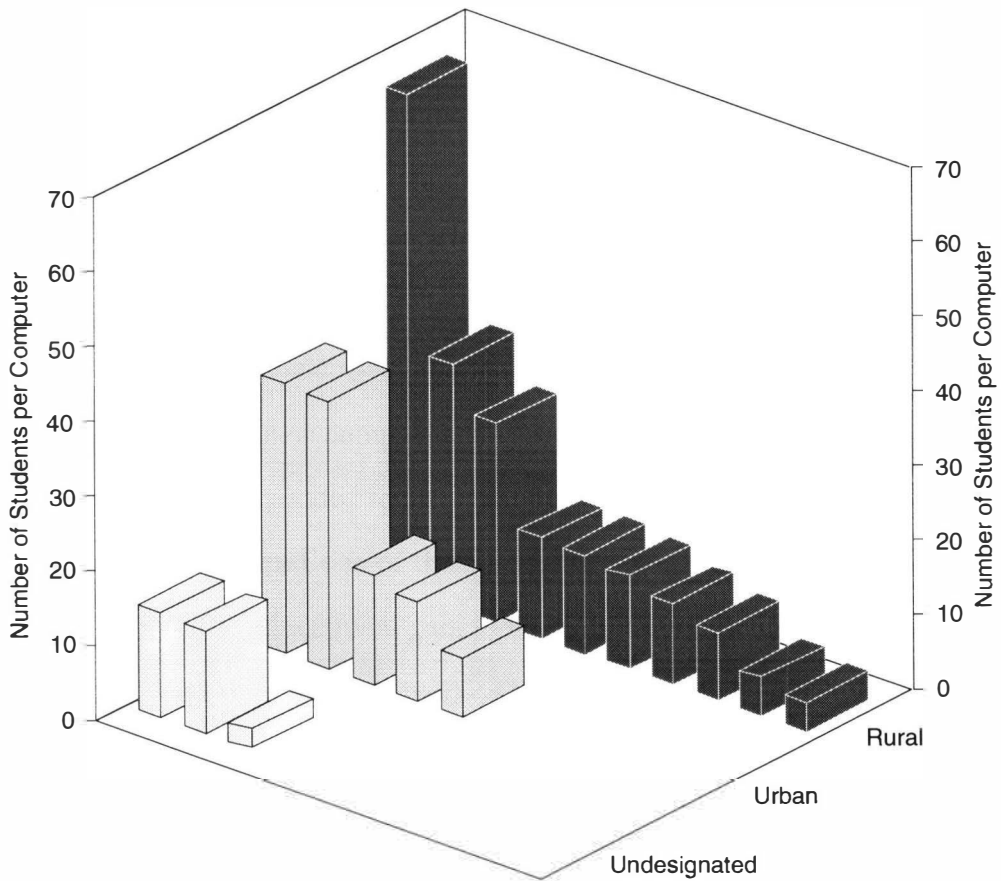


Figure 27. Relationship Between Student/Computer Ratio and Environment Designation of Each School.

designation do not have any significant influence on student/computer ratios. The sample size is too small to justify further statistical analysis and extrapolation of these findings to other areas in Michigan.

Computer capacity was also found to be independent of student enrollment and environmental designation. One case in point is Delton Kellogg High School, which is a rural school with a relatively small enrollment of 567 students. This school has one of the lowest student/computer ratios (5:1) and could operate the most GIS programs both at the minimum (5) and recommended (2) hardware levels. By contrast Portage Central High School is an urban school with the second largest enrollment of 1133 students, a student/computer ratio of 8:1, and computers capable of operating 2 GIS programs at minimum levels and 1 at recommended levels.

Discussion

The investigation into the technological status of high schools in the study area examined four issues. Firstly, do high schools have the necessary hardware to operate GIS programs or would new computers have to be purchased? Just over thirty percent of the schools which responded to the questionnaire were found to be technologically prepared to operate at least one of the GIS programs under consideration. Even so, there is probably little educational gain to be achieved by operating GIS programs at minimum hardware requirement levels. The programs run too slowly and the more complex functions often do not work at all. Consequently, looking at the analysis on the basis of recommended hardware requirement levels, only 21% (4) of the respondent schools could operate a GIS at these levels, two of which could operate Map Factory, one of these had 16 computers and the other over sixty machines with this capability. Eleven percent (2) of schools in the study area could operate MapInfo (PC) with existing hardware. One of these schools could also operate IDRISI. In the latter two

schools the computer laboratories contained several types of machines and it was not possible to determine from the data collected how many computers had the necessary capability. No school could satisfactorily operate ArcView (PC or MAC), MapInfo (MAC), or Maptitude. It would seem apparent, therefore, that few schools could introduce GIS using existing hardware and their choice of program would be severely limited.

The second question addressed whether social studies classes have access to computer laboratories. In 58% percent of the respondent schools, social studies classes did not have access to computers. Even within the six schools which could operate a GIS at recommended hardware levels, 50% deny computer access to social studies classes. This is mostly a result of the computer laboratories being fully scheduled for use by computer science and business classes.

The last two questions considered the effects of school size and of the rural or urban nature of the school's service area on the student/computer ratio and computer capacity. Neither factor was found to be numerically influential. Some small rural schools were found to be as well equipped as some large urban schools. The more favorable student/computer ratios found in very small rural schools with enrollments of 197 to 289 students resulted from the presence of a single computer laboratory of 20 to 25 machines. Unfortunately, several much larger urban and rural schools with 747 to 1006 students also had one computer laboratory. One urban school with over a thousand students had only 28 Apple IIe computers. Computer capacity was also found to be independent of student enrollment and environmental designation. The school which could run the most GIS programs at recommended hardware levels was a rural, medium-sized school with a 5:1 student/computer ratio. The second most GIS capable school was an urban school with twice the enrollment and a 8:1 student/computer ratio.

Therefore, within this study area there would appear to be little opportunity for social studies classes to incorporate GIS into the curriculum without extensive computer upgrades and changes in school policies towards computer accessibility. However, should a school wish to integrate this technology into the curriculum, the two GIS programs with the lowest computing capacity requirements are MapInfo for the PC, a vector system, and Map Factory for the Macintosh, a raster system.

CHAPTER VII

DEFINING THE ROLE OF GIS IN HIGH SCHOOL GEOGRAPHY EDUCATION IN A SELECTED REGION OF SOUTHWEST MICHIGAN

Introduction

The principal research question posed in this inquiry was, “Could GIS be successfully integrated into high school geography education in a selected region of southwest Michigan?” In attempting to answer this question this research focused on three aspects of the problem. Firstly, the investigation strove to demonstrate how GIS could be integrated into the high school geography curriculum in Michigan. Secondly, GIS software programs were evaluated using three techniques to identify those suitable for use in high schools, and thirdly, the high schools in the study area were assessed for their technological capabilities to operate GIS programs. The conclusions reached through this inquiry will be summarized within this framework.

GIS in the High School Geography Curriculum in Michigan

After sixty years of decline to a position of relative obscurity in the American school curriculum, geography is beginning to experience a renaissance as a result of numerous national and state initiatives. Within Michigan, geography, as a distinct and separate strand of social studies, is now featured in a recommended state core curriculum, has a framework of content standards and benchmarks linked to critical grade levels throughout K–12 education, and will be the subject of high stakes assessment beginning in 1999. Geography as part of social studies has been given equity in the Michigan school curriculum, alongside English, mathematics, and science.

The concepts, content, and skills have been clearly defined. The final three cross-cutting content standards of the Michigan Framework for Social Studies Education: Content Standards and the teaching standards in Powerful Authentic Social Studies: Standards for Teaching (Michigan Department of Education, 1995, 1996) imply this content should be taught through an inquiry process, which will engage students in higher cognitive processes and problem solving. As Wiske and Houde (1988) suggest, incorporating guided inquiry into the average secondary school will require a fundamental change in the educational paradigm. Teachers will require not only training in this new approach, but new tools to enable them to institute these innovations.

Decades of research have elucidated the cognitive and pedagogical advantages of integrating computer technologies into the classroom. However, it is not the technologies themselves which mediate learning, but the thought processes which are engendered by the technologies which foster erudition (Jonassen, 1988). Therefore, it is essential to provide software which will stimulate the most productive thought processes. In addition, Learning Theory suggests the most effective types of learning experiences are those which engage students actively in the learning process, using as many senses as possible (Maffei, 1986). Therefore software which requires direction and control by the student will provide the more dynamic interaction (Jonassen, 1988). Such self-directed, exploratory activities not only exploit the unique potential of the computer, but prepare the student to deal with the complex demands of the modern problem oriented and increasingly technological society (Hazen, 1985). GIS is one such tool which may be able to energize students into becoming critical thinkers, allowing for various learning styles, and fostering collaborative teaching strategies (Marran, 1994).

If the introduction of GIS into the classroom has numerous cognitive and

pedagogical benefits, it must still correspond with the developmental level of the students and learning objectives of the curriculum (Liben, 1994, Jenkins, 1991). There has been no research on the cognitive demands of GIS tasks. Therefore, teachers must exercise their own judgment on what their students can and cannot comprehend. The curricular match also has to be examined on a school by school basis. However, in Michigan with the adoption of state geography content standards and assessment it is possible to align generic GIS projects with the broad context of the implied curriculum. This research has suggested GIS could be used as a tool in an inquiry approach to learning in geography education in Michigan.

The Identification of Suitable GIS Software

Three techniques were used to evaluate the suitability of GIS software for high school classrooms. Since no educational software has been designed specifically for K-12, an initial selection was made from the vast array of business and higher educational programs on the basis of low cost and a Windows interface standard. Of those identified, four were chosen for further study: ArcView, IDRISI, Map Factory, and MapInfo. These programs were representational of both raster and vector formats and PC and Macintosh environments. With the addition of a Manual GIS, constructed of paper maps and transparencies, the selected GIS were subjected to a systematic evaluation to assess their ease-of-use. Although there were some severe limitations to the technique used, it was thought to be a realistic simulation of novice use. MapInfo and ArcView, vector GIS, were deemed simplest to use over a wide array of functions. Map Factory was found to be the easier of the two raster programs.

The third stage in the evaluation was conducted by sixteen high school students recruited from the Kalamazoo Area Math and Science Center and Loy Norrix High School. The students compared the performance of the five GIS selected for the

systematic evaluation on two problem solving exercises, one involving visual overlay and the other spatial analysis. They ranked the various GIS based on several criteria and described what they liked and disliked about individual programs. The students displayed a considerable bias towards computerized GIS, despite recognizing some of the advantages of a manual version. Caution has to be exercised in interpreting the results of this evaluation because of the small sample size. However, certain trends did emerge. ArcView was preferred for performance on visual overlay, which might be expected since a map layer can be overlaid with a single click of the mouse. For spatial analysis IDRISI and MapInfo were equally favored. There was no single criterion upon which the students appeared to base their preference for the program they would most like to use again. IDRISI and MapInfo received an equal number of first rankings for the program they would most like to use again. However, when first and second rankings were considered together the picture changed, and ArcView became most popular followed by IDRISI and MapInfo. Map Factory was least preferred. The majority of students voted MapInfo as the most fun to use, but no one thought Map Factory was fun. Some interesting relationships between variables emerged. Age and gender seemed to affect GIS preference for some programs. The 16 and 17 year old boys preferred IDRISI, whereas all the girls preferred MapInfo. In light of the small sample size in this research, these relationships will require more extensive study to validate.

It was apparent the students in this study and the researcher evaluated the GIS programs from different perspectives. The researcher considered cost and ease-of-use the most critical factors in software selection, an administrative or teacher's perspective. From the students' view point, cost was not an issue. However, ease-of-use was only one of several factors which influenced student preferences. Performance appeared to be an important contributory factor in student GIS selection, which suggests they want

a program which provides good visualization of problem solving.

Based on the results of this research, it is doubtful if any of the four GIS are really suitable for high school use. The primary disadvantages found are described below. ArcView, while having large, clear maps and performing some operations very easily, lacks some of the functionality of other programs and provided poor visualization of the results of the spatial analysis. The lack of a hardcopy tutorial and fully indexed manual is a serious drawback, as is the unnecessarily complex terminology it uses. IDRISI has wide ranging functionality, but it is too complex for high school use. For secondary students, the dialogue boxes need to be simplified, maps should display automatically, and additional flexible functionality needs to be provided for generating output. The manual also needs to be simplified and fully indexed. Map Factory has many easy to use features and it will operate on low powered machines. However, students did not rank it highly. The scripting language seems unnecessarily complex compared to the dialogue boxes of Map Factory's predecessor, Map II. The maps should be displayed fully sized and in color for the secondary school environment. MapInfo was well received by the students. However, they did not encounter some of the inherent problems of this program. Choropleth maps, which students are likely to use extensively, are difficult to create as they can only be saved in a 'workspace', and there appears to be no way to save custom color palettes. For school use, maps should automatically fill the screen, be colored, the terminology should be simplified, and output functionality improved. Software manufacturers interested in providing GIS for K-12 need to carefully study the demands of the curriculum and perhaps more importantly the perceptions and requirements of the students.

The Technological Status of High Schools in the Study Area

The third and last part of the inquiry was an assessment of computing capacity, access, and student/computer ratios in high schools. The study area included urban and rural schools with a wide range of student enrollment. Computer provision was found to vary widely across all school sizes and environments. Few schools had student computers capable of operating GIS programs at manufacturer's recommended hardware requirement levels. Costs involved in upgrading computer hardware are an important consideration. The ArcView White Paper GIS in K-12 Education suggests "With less than \$3,000 investment (March 1995), schools can have a new, full featured, high powered computer ready for classroom needs and a site license for a powerful starter package of software and basic data." (ESRI, 1995). This will provide one computer using ArcView. Is this a cost-effective investment? Can GIS be successfully and usefully integrated into the curriculum using one computer? The answer to both these questions is no. GIS is not going to make a significant impact on geography education if students cannot work collaboratively on group or class GIS projects for an extended period of time.

Low computing capacity is a fundamental problem, but accessibility may indeed be the most disturbing issue. In over half the schools studied, social studies classes did not have access to the computers because they were being fully utilized throughout the day by other disciplines. Schools need to address this problem in innovative ways. Some are providing mobile laboratories, which consist of several computers and associated hardware which are housed on carts that can be moved into the classroom as needed. Another solution is a small laboratory which could be booked on an occasional or block time basis by any discipline.

Conclusion

Could GIS be successfully integrated into high school geography education in a selected region of southwest Michigan? Now that geography has a clearly defined position in the K–12 curriculum of Michigan schools, GIS has a place as a tool which can engage students actively in inquiry learning, stimulate higher cognitive processes, and provide technological skills. It can be integrated into the high school geography curriculum in Michigan. However, the schools are not equipped to embrace this technology at the present time using the available business or higher educational programs. Perhaps the major drawback to GIS implementation is the software. While the evaluations conducted in this research identified programs which were more suitable in some respects than others, each had serious limitations. None were designed for the young student user, each required high capacity powerful machines, and their interfaces were not intuitive, making the learning curves unnecessarily long and steep.

Recommendations

Education proceeds by a series of small innovations. Because it is so highly decentralized, because funds are always short, because the mission is split into so many different directions, education cannot concentrate resources and make a great leap forward in one direction.
(Robert F. Tinker, 1994.)

The recommendations from this research fall into three categories: further research, software development, and classroom organization and management. Before GIS can bring some of its obvious advantages to the average classroom, detailed research has to be performed on the cognitive requirements of GIS tasks to determine the kinds of spatial analysis appropriate for students at different levels, and on the type and extent of GIS education and training needed by teachers and by students to use GIS effectively. Research is also needed to establish if GIS, when used in an inquiry-based

approach to learning, helps students to become critical thinkers. Only then can suitable software be designed, appropriate curriculum materials created, and adequate teacher training be instituted.

Software has to be designed specifically for K–12 education, with an interface and functionality directed to the requirements of the young student and of the curriculum. Terminology must be standardized, preferably adapting the already comprehensive and well accepted cartographic vocabulary. Separate documentation will have to be written for teachers and students, assuming little or no technological background. Software designers will also have to accept the reality of the school situation at this time and recognize that to service this market effectively requires programs which will run on existing hardware.

Once all these pieces are in place, GIS will have to face one of the largest hurdles to its full integration into the curriculum, that of institutional acceptance. New technologies are frequently seen as a threat, involving disruption of known classroom patterns and necessitating the need to learn new skills. GIS will have to demonstrate its ecological validity to convince teachers and administrators that the required fundamental change in classroom practice and the increases in technological and financial support of school bureaucracy will be worth while.

Appendix A
Systematic and Student Evaluation—Data Set Preparation

DATA SET PREPARATION

The data set used in the systematic and student evaluation consisted of six map layers for Thornapple Township in Barry County, approximately thirty miles north northeast of Kalamazoo (Table 33). This data set was available in vector-based format in C-Map from the Barry County Mapping Department and in raster-based format, with the exception of the map layer ELEVATION, in Map II from the Geography Department of Western Michigan University, where it was used in a GIS course.

Table 33
Systematic and Student Evaluation Data Set

| Map Layer | Description and Source Map | Number of Classes |
|-----------|---|-------------------|
| Thornel | Elevation point data (USGS 1:24,000) | 17,000 points |
| Th94 | Land cover/use 1994 (Miris 1978) | 30 |
| Lakes | Lakes (Miris) | 2 |
| Rivers | Rivers (Miris) | 2 |
| Roads | Country roads (Miris) | 2 |
| Highway | Highway M 37 Hastings to Grand Rapids (Miris) | 2 |

USGS—United States Geological Survey.
Miris—Michigan Resource Information System.

Each image is geo-referenced to the State Plane coordinate system (1927). The topographic map was created by the researcher during an internship with the Barry County Mapping Department by digitized the ten foot contour lines of 1:24,000 USGS quads. The other map layers were created by the Mapping Department from Miris

maps (Michigan Department of Natural Resources) and modified using aerial photographs and parcel maps. In raster format each image has cell resolution of 160 feet, and a file size of 200 rows and 200 columns containing 4 or 8 bit data. This data base had to be converted into different formats for entry into the GIS programs.

File Preparation

To allow for unbiased evaluation of the GIS programs, care was taken to ensure all the map layers looked as similar as possible in each of the GIS by using predetermined colors for each map layer. An effort was also made to create raster and vector maps which looked similar and contained the same information. For instance, information detailed in the legends of raster maps was added to the attribute tables of the vector maps, e.g., the explanation of landuse codes.

The six map layers were taken from C-Map and prepared for importing into the GIS programs in the following manner:

1. Thornel was a topographic map containing over 17,000 points. This was exported out of C-Map as an Arc coverage (ArcInfo file). In this project a hypsometrically tinted elevation map drawn at 20 foot contour intervals was required. To achieve this, the Arc coverage was converted to a point grid using ArcInfo POINTGRID. A 200 by 200 grid was used and a look-up table was created to convert the elevation range of 700 to 1000 feet to 70 to 100, so it could be exported as an ERDAS 8 bit data grid file. The file was then imported into IDRISI using the software specific module ERDIDRISI. Here it was converted into a point vector file using POINTVEC. The satisfactory running of the interpolation module required that the number of pixels be thinned. This was done by a factor of two using CONTRACT. INTERPOL was then run using a search radius of 6 cells. The map was projected back onto its original coordinate system (State Plane, 1927) using RESAMPLE. The map

was recoded with RECLASS to simulate a 20 foot contour interval. Since the elevations were at this point reduced by a factor of 10, 2 foot intervals were used. The file was exported using the software specific module ERDIDRISI as an ERDAS 8 bit file. This was taken into ArcInfo and GRIDPOLY used to create a polygon file. A look up table was required to re-establish the correct elevation range of 700 to 1000 feet. This created a somewhat stepped polygon map, but it was deemed adequate for the purpose. This file was named ELEVATION.

2. The lake map layer was available in C-Map and Map II. It was exported from C-Map as an Arc line coverage. This coverage was converted into a polygon file. This was done so the lakes could be colored with a fill pattern, following map convention and allowing the vector and raster portrayals to look similar. These files were renamed LAKES.

3. The river map layer was available in C-Map and Map II. It was exported from C-Map as an Arc line coverage. These files were renamed RIVERS.

4. The country roads map layer was available in C-Map and Map II. It was exported from C-Map as an Arc line coverage. These files were renamed ROADS.

5. The highway M37 map layer was available in C-Map and Map II. It was exported from C-Map as an Arc line coverage. These files were renamed HIGHWAY.

6. Th94 was the landuse layer. It was available in C-Map, Map II, and MapInfo. It was exported from C-Map as an Arc coverage. These files were renamed LANDUSE.

File Conversion

1. ArcView—the six map layers as Arc coverages could be used directly by ArcView. Two tables were constructed. In one, CODES.dbf, the landuse codes were provided with a descriptive interpretation, e.g., 210 Cropland. This was joined using a

relational join to the attribute table of LANDUSE. A second table, HEIGHT.dbf, was constructed and joined to the attribute table of ELEVATION to provide a more accurate description of each contour interval, e.g., 700 700–719 ft. Both attribute tables and the table CODES.dbf were customized so that only the relevant information was shown and the column headings were given more descriptive aliases, where necessary. See Tables 34, 35, and 36 below. It was found that unless the shape field was made visible, shapefiles could not be made as required in one of the Student Evaluation Exercises. The shape field was also made visible in the ELEVATION attribute table for consistency. Each map layer was custom colored using predetermined shades.

Table 34

Attribute Table for ELEVATION

| Visible | Field | Alias |
|---------|-----------|------------|
| √ | Shape | |
| √ | Elev_id | Polygon id |
| | Area | |
| | Perimeter | |
| | Elev_ | |
| √ | Grid_code | Elevation |
| | ELEVATION | |
| √ | HEIGHT | Height |

Table 35
Attribute Table for LANDUSE

| Visible | Field | Alias |
|---------|------------|--------------|
| √ | Shape | |
| √ | Th94_id | Polygon id |
| | Area | |
| | Perimeter | |
| | Th94_ | |
| √ | Label | Landuse Code |
| | Newfield | |
| √ | Descriptio | Description |

Table 36
Table for CODES.dbf

| Visible | Field | Alias |
|---------|------------|--------------|
| √ | Newfield | Landuse Code |
| √ | Descriptio | Description |

2. Map Factory—The five of the map layers: LAKES, RIVERS, ROADS, HIGHWAY, and LANDUSE could be imported into Map Factory from Map II. The final layer, ELEVATION, had to be converted from an Arc coverage into a Tiff file using MIPS, before it could be imported into Map Factory. Descriptive labels were added to every item in each legend. This was necessary as no attribute tables are

displayed when the maps are queried. Each map layer was custom colored using predetermined shades.

3. MapInfo—LANDUSE was already available in MapInfo format. The Arc coverage line and polygon files, LAKES, RIVERS, ROADS, and HIGHWAY, were converted into DXF files in ArcInfo using ARCDXF. A header had to be included to retain the coordinate information. These could then be imported into MapInfo. ELEVATION contained attribute information which would be lost if a conversion to a DXF file was used. The ELEVATION Arc coverage file was therefore converted into C-Map and then into a MIF file. Since this translation does not handle polygons within polygons very well, which is the predominant form of polygon on this map, each polygon attribute had to be checked for accuracy and corrected where necessary. A table, CODES, was constructed to provide a description of each landuse code, e.g., 210 Cropland. This was then joined to the attribute table of LANDUSE, using a relational join. A second table, HEIGHT, was constructed and joined to the attribute table of ELEVATION to provide a more accurate description of each contour interval, e.g., 700 700–719 ft. Each map layer was custom colored using predetermined shades.

4. IDRISI—Difficulties were experienced in importing any file which had no feature on its western margin. The western edge of the map was consistently shifted to where the first feature began, so the map layers would not overlay correctly. Therefore it was necessary to take the LAKE and HIGHWAY files into ArcInfo and in ARCEDIT screen digitize a line down the western edge. The LANDUSE file was used as backcoverage to ensure the western edges were all correctly placed to allow map alignment. IDRISI can display, but not analyze, vector files. The procedure for displaying these vector files is much simpler than a conventional raster overlay. Therefore, since the line files: RIVERS, ROADS, and HIGHWAY, were only to be

displayed and not analyzed, it was decided to make use of this vector display option. These vector line files were converted in ArcInfo into “Arc ungenerate” files which were imported into IDRISI using the software specific module, ARCIDRISI. The LAKES and LANDUSE files were converted using POLYGRID in ArcInfo into a 200 by 200 grid. They were exported as ERDAS 8 bit files. A look-up table had to be constructed for LANDUSE so that the landuse codes were translated from a range of 112 to 622 into 1 to 30. These two files were imported into IDRISI using the software specific module ERDIDRISI. The correct landuse codes and descriptions were added to the categories 1 through 30 in the document file in Data Entry EDIT, so they would be displayed in the map legend. The map showing topography had already been taken into IDRISI in order to translate it into a more acceptable form for use in all the GIS (see above). After interpolation and resampling the file was recoded such that 2 foot intervals were placed in categories from 1 to 15. Using Data Entry EDIT the correct elevation range, 700 to 1000 ft, was added to each category, in the document file, so they would be displayed in the map legend. Each map layer was custom colored using predetermined shades.

5. Manual GIS—The manual GIS was constructed using ArcView. A layout template was developed, so all the map files could be displayed in an identical manner. Each map file was then projected into the template, the legends individually aligned so they would remain visible in all the overlay combinations to be used. The maps were then printed in color on an Apple StyleWriter ink jet printer. ELEVATION and LANDUSE were printed on high quality coated paper. LAKES, RIVERS, ROADS, and HIGHWAY were printed on transparencies. A table called CODES was constructed in Microsoft Word to identify the landuse codes.

The preparation and conversion of the map files is summarized in flow diagrams in Figures 28, 29, 30, and 31.

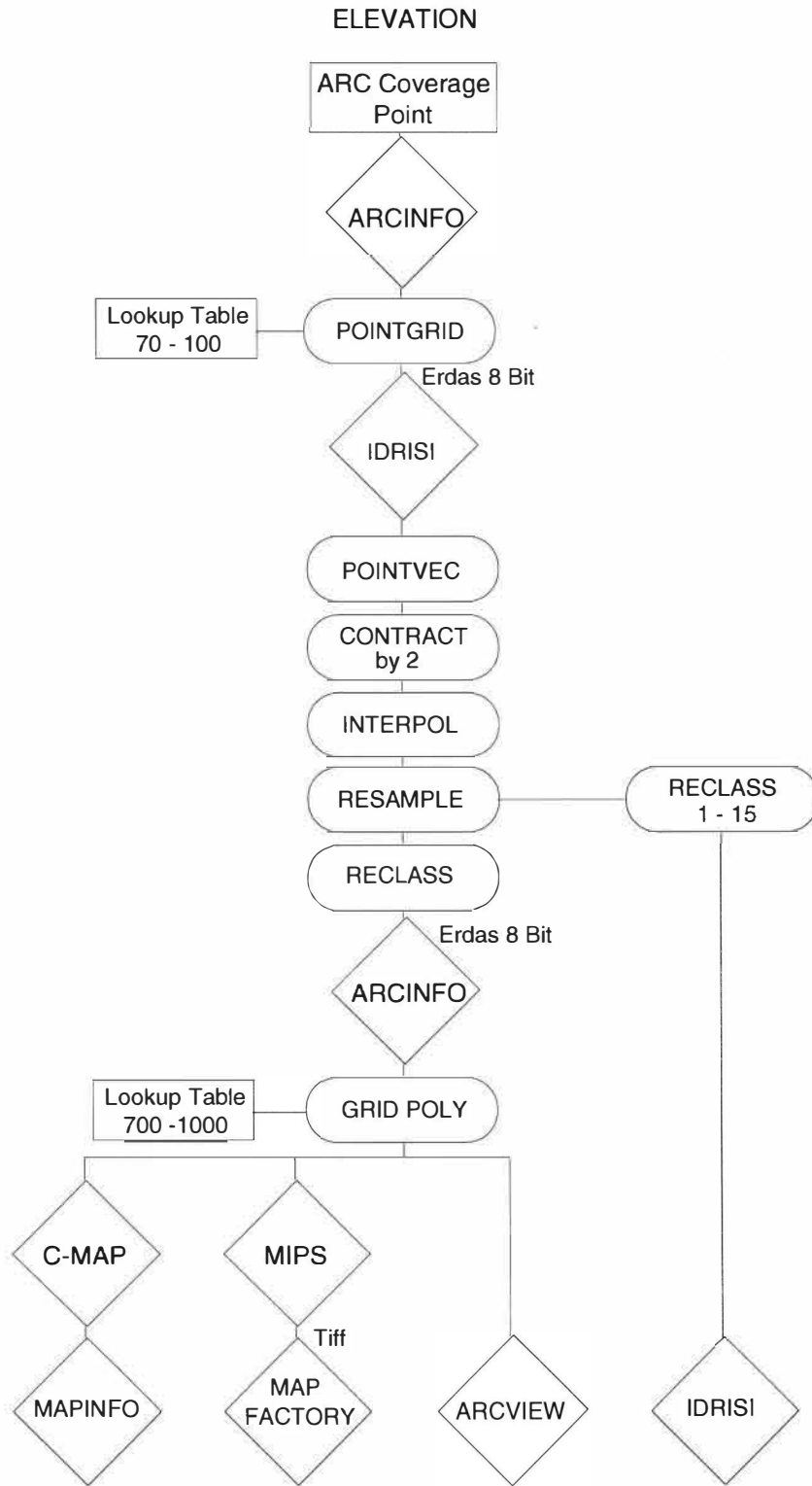


Figure 28. Preparation and Conversion of ELEVATION Map File.

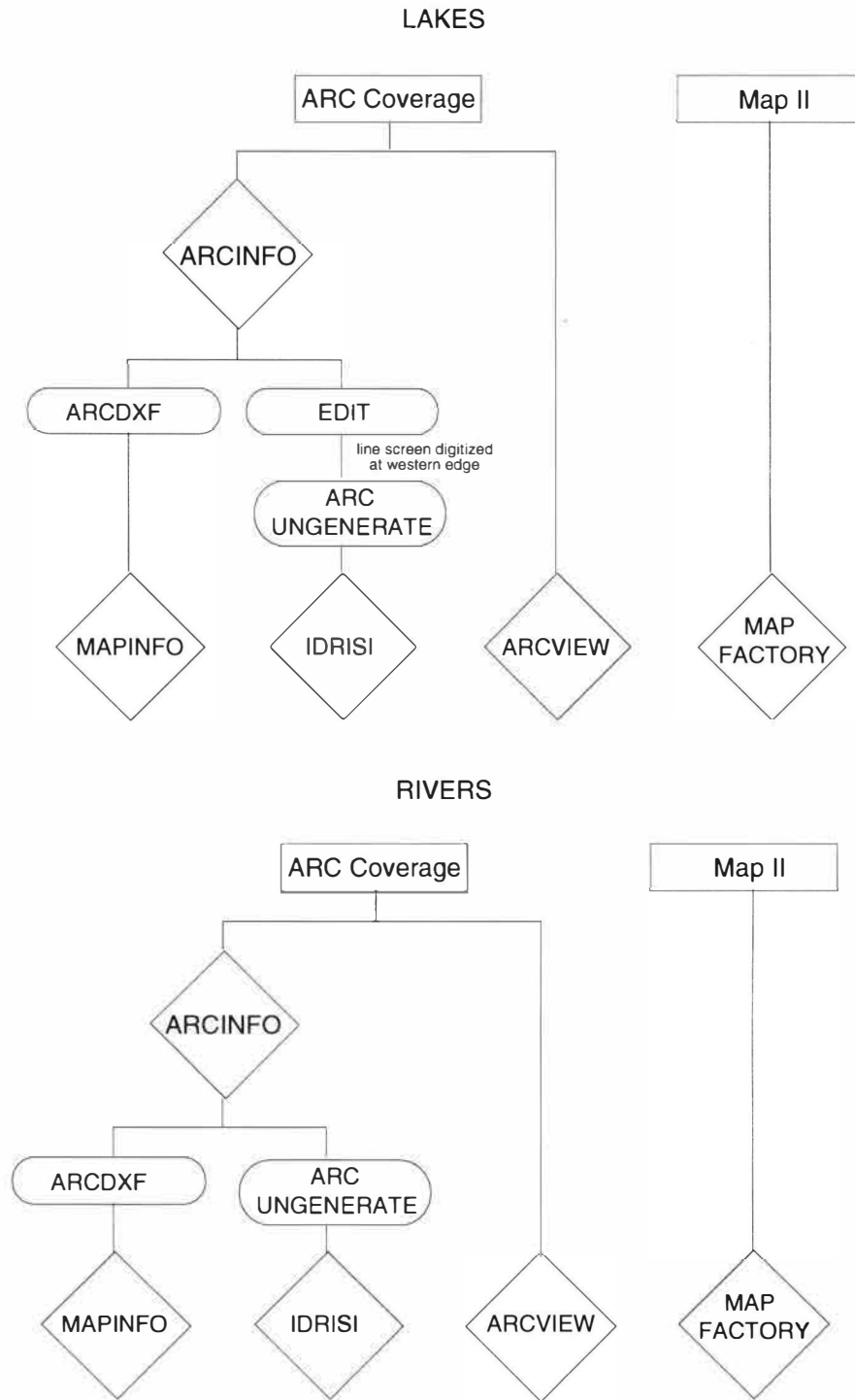


Figure 29. Preparation and Conversion of LAKES and RIVERS Map Files.

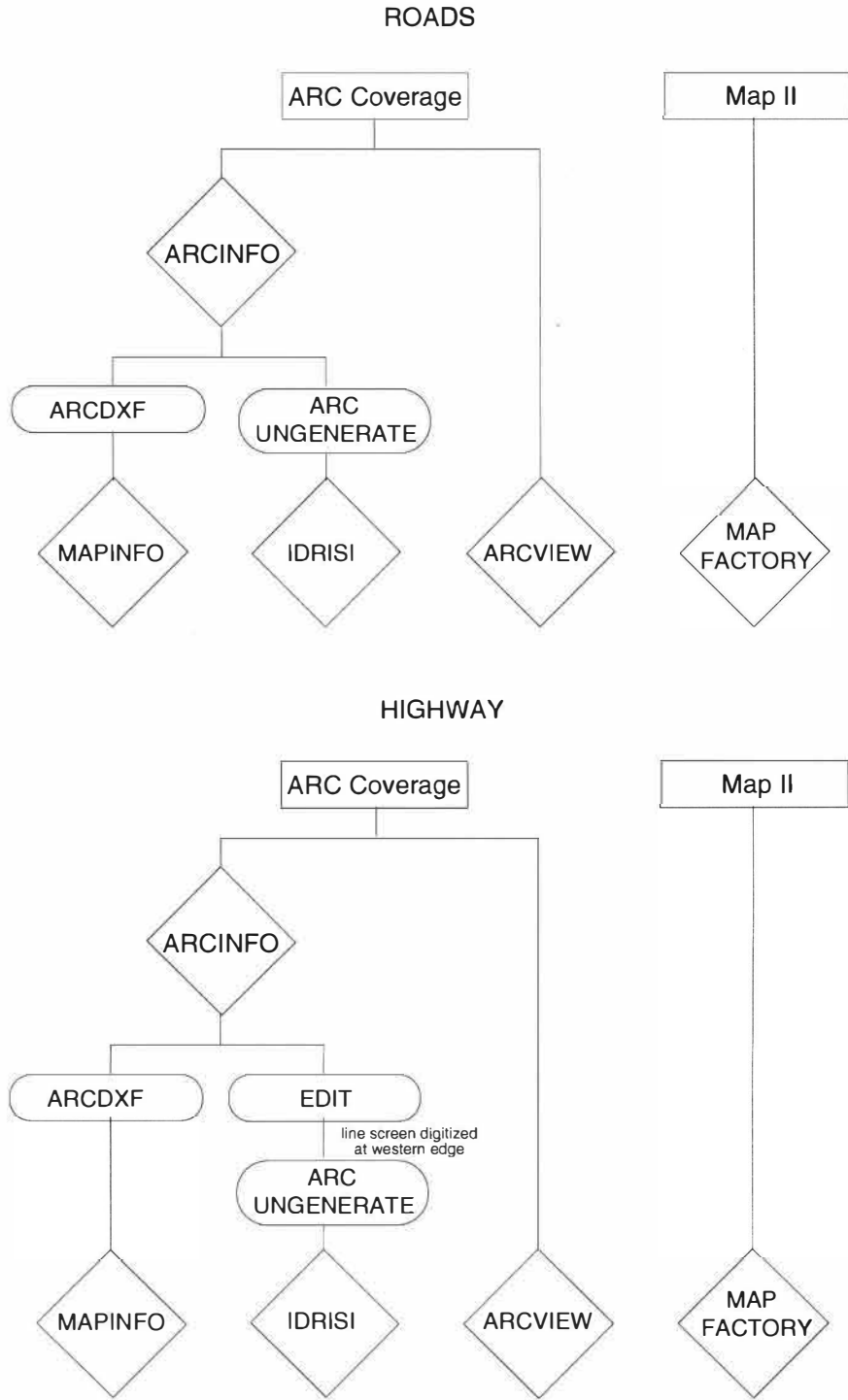


Figure 30. Preparation and Conversion of ROADS and HIGHWAY Map Files.

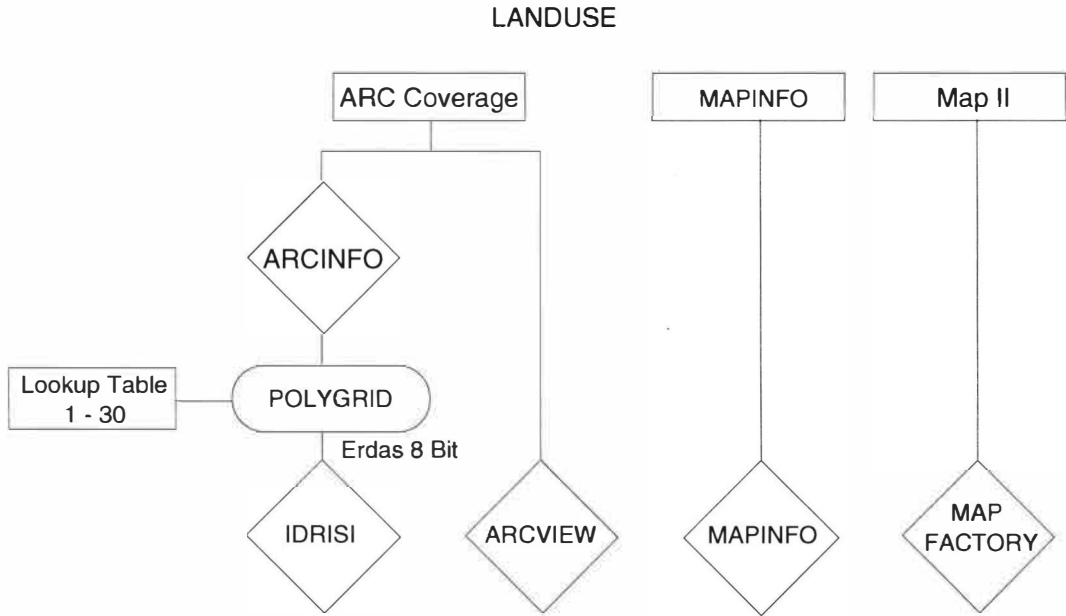
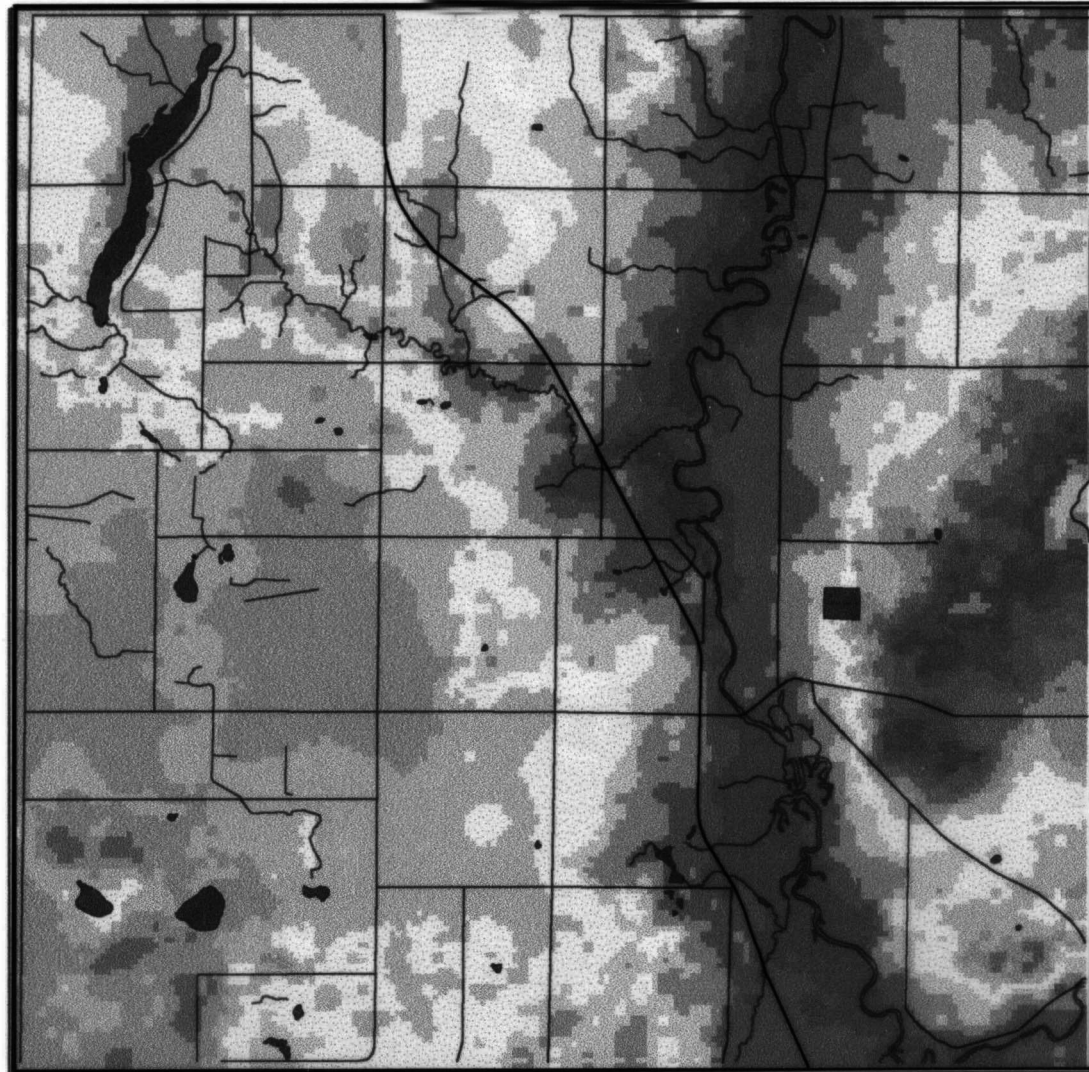


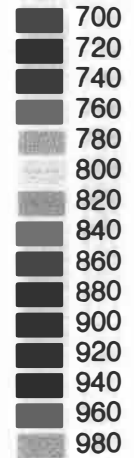
Figure 31. Preparation and Conversion of LANDUSE Map Files.

Appendix B
Manual Geographic Information System
(Reduced Size)

HIGHWAY




ELEVATION



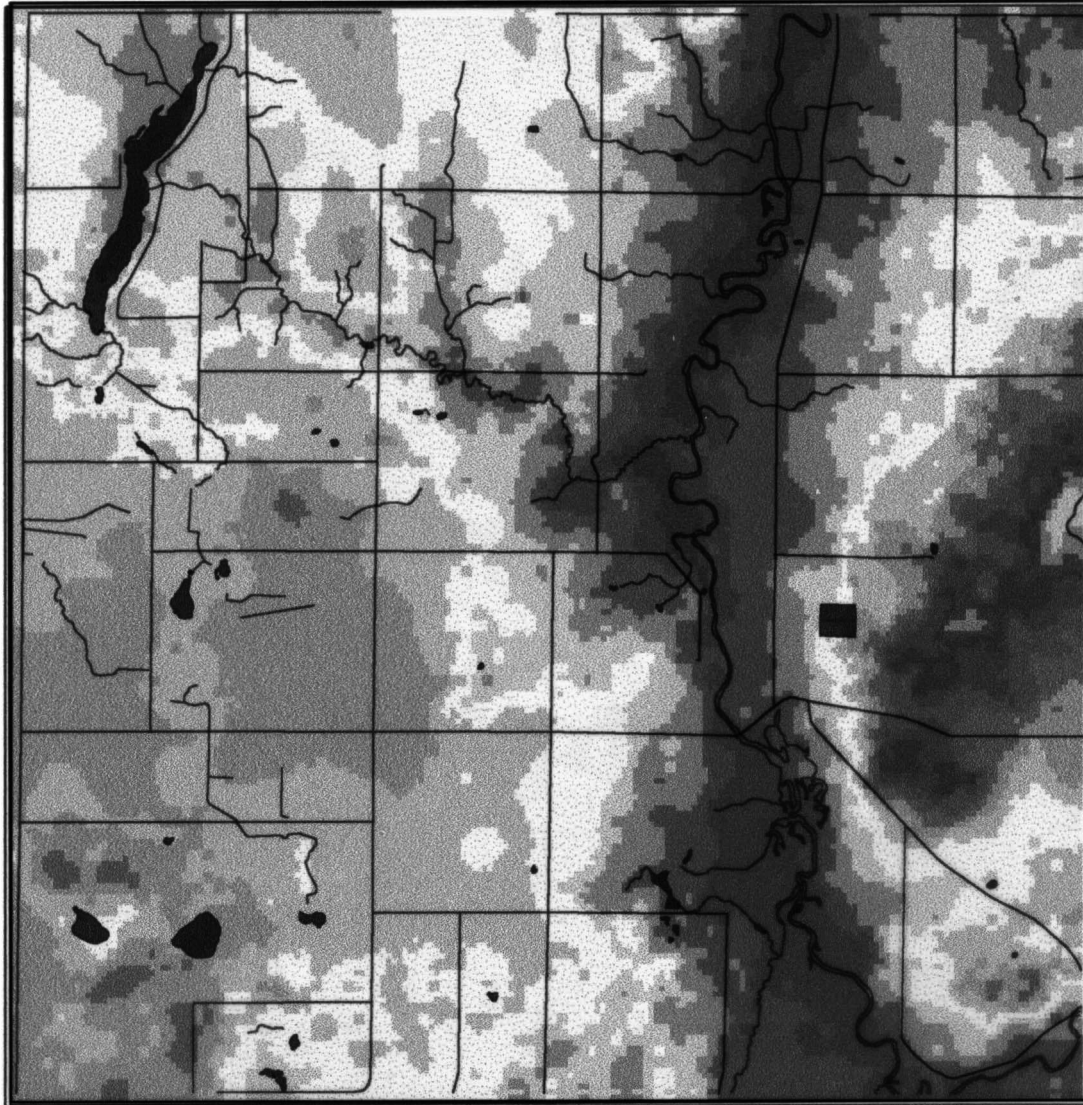
 LAKES

 RIVERS

 ROADS

 HIGHWAY

ROADS



ELEVATION

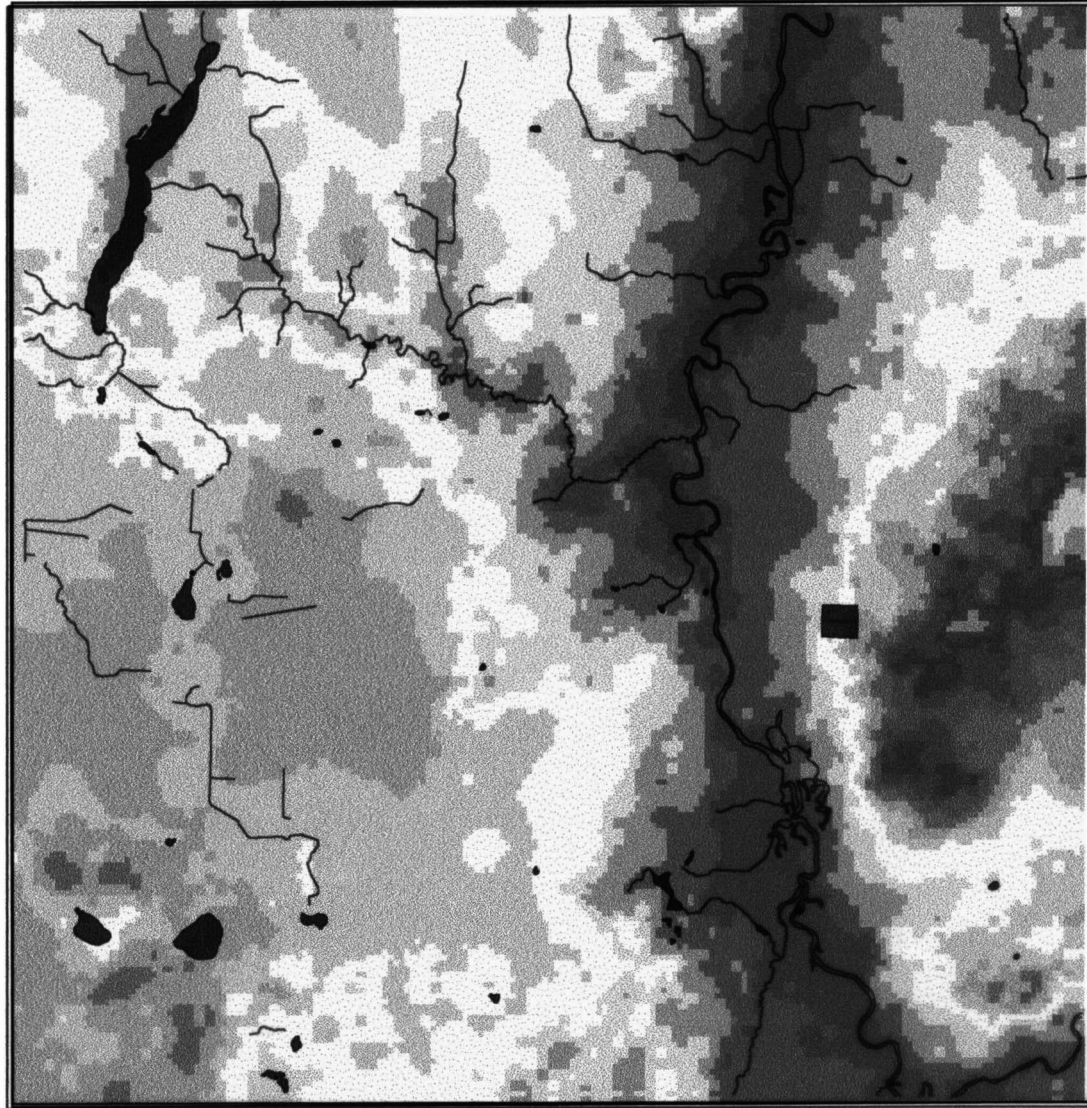


■ LAKES

∩ RIVERS

∩ ROADS

RIVERS



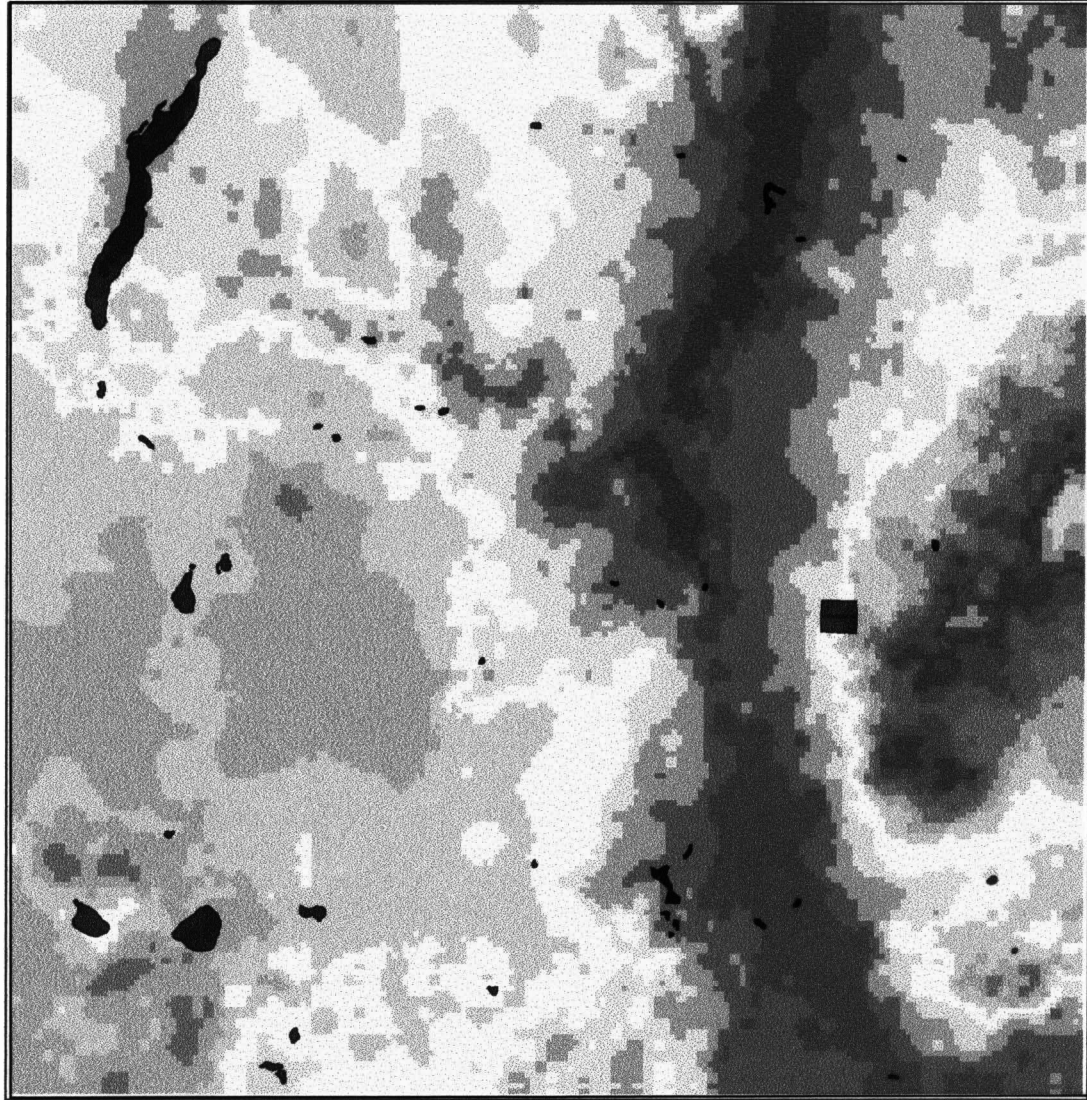
ELEVATION

- 700
- 720
- 740
- 760
- 780
- 800
- 820
- 840
- 860
- 880
- 900
- 920
- 940
- 960
- 980

LAKES

RIVERS

LAKES

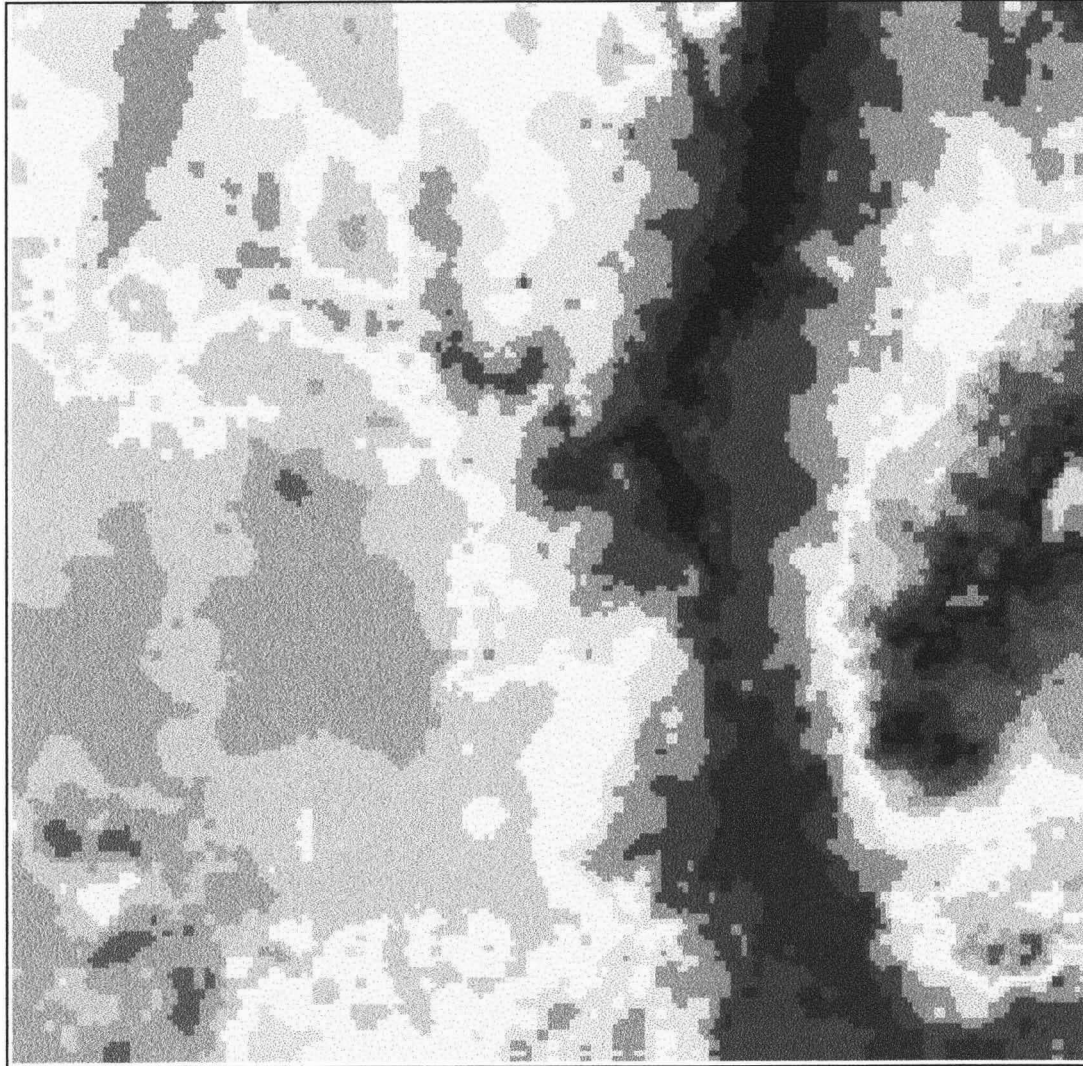


ELEVATION

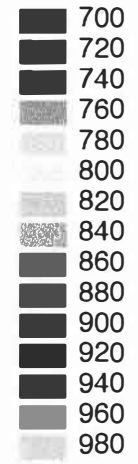


■ LAKES

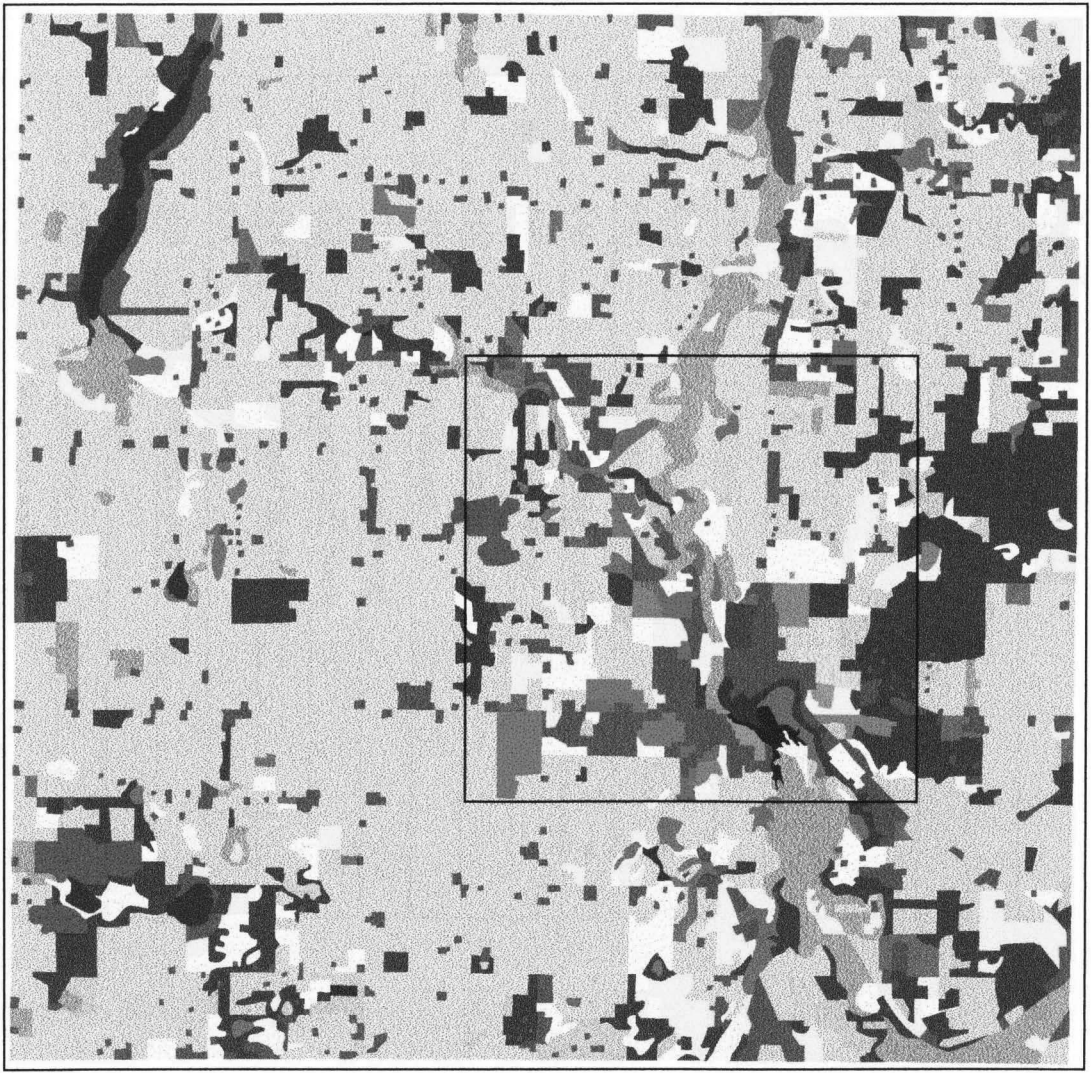
ELEVATION



ELEVATION



LANDUSE



LANDUSE

- 112
- 113
- 115
- 121
- 122
- 124
- 126
- 130
- 145
- 146
- 171
- 193
- 194
- 210
- 230
- 240
- 290
- 310
- 320
- 412
- 413
- 414
- 421
- 423
- 520
- 530
- 611
- 612
- 621
- 622

CODES

| Landuse Codes | Description |
|---------------|---------------------------|
| 112 | Multi-family/low rise |
| 113 | Single family/duplex |
| 115 | Mobilehome park |
| 121 | Central Business District |
| 122 | Shopping mall |
| 124 | Strip mall |
| 126 | Institutional |
| 130 | Industrial |
| 145 | Communications |
| 146 | Utilities |
| 171 | Open pit extractive |
| 193 | Outdoor recreation |
| 194 | Cemeteries |
| 210 | Cropland |
| 230 | Confined feeding |
| 240 | Permanent pasture |
| 290 | Other agriculture |
| 310 | Herbaceous openland |
| 320 | Shrubland |
| 412 | Central hardwood |
| 413 | Aspen/white birch |
| 414 | Lowland hardwood |
| 421 | Pine |
| 423 | Lowland conifer |
| 520 | Lakes |
| 530 | Reservoirs |
| 611 | Wooded wetland |
| 612 | Shrub/scrub wetland |
| 621 | Aquatic bed wetland |
| 622 | Emergent wetland |

Appendix C
Protocol for Systematic Evaluation

SYSTEMATIC EVALUATION

NAME:

COST : single copy Licence
 student

PLATFORM

PC Mac Both Workstation

HARDWARE REQUIREMENTS

Memory (RAM)

Hard disk capacity

DATA REPRESENTATION

Raster Vector Raster/display vector Vector/display raster

DATA ENTRY

Tablet digitizing

Scanned maps

Screen digitizing

Common data formats

Registration

by relative position

by absolute position

MAP MANIPULATIONS OPERATIONS

| Operations available | Number of actions need to implement | | | | | | | | | | |
|---|-------------------------------------|---|---|---|---|---|---|---|---|----|-----|
| <input type="checkbox"/> Map retrieval | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Z oom | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Find point coordinates | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Search by attribute | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Classification | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Find point coordinates | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Attribute editing | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Rescale | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Subset | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |

MEASUREMENT OPERATIONS

| Operations available | Number of actions need to implement | | | | | | | | | | |
|--|--|---|---|---|---|---|---|---|---|----|-----|
| <input type="checkbox"/> Distance between object pairs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Area of polygon/zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Perimeter of polygon/zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |

LOCATIONAL ANALYSIS

| Operations available | Number of actions needed to implement | | | | | | | | | | |
|---|--|---|---|---|---|---|---|---|---|----|-----|
| <input type="checkbox"/> Visual overlay | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Logical overlay | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Buffer zone generation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |

DATA OUTPUT

Printer compatibility

- Dot matrix
 Ink-jet
 Laser

| Operations available | Number of actions needed to implement | | | | | | | | | | |
|---|--|---|---|---|---|---|---|---|---|----|-----|
| <input type="checkbox"/> Layout window | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Map annotation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Feature labels | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Color | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Line styles | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Standard graphic symbols | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |
| <input type="checkbox"/> Map printing | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ___ |

Quality

Poor Excellent
 1 2 3 4 5

Tutorial Hardcopy On-line

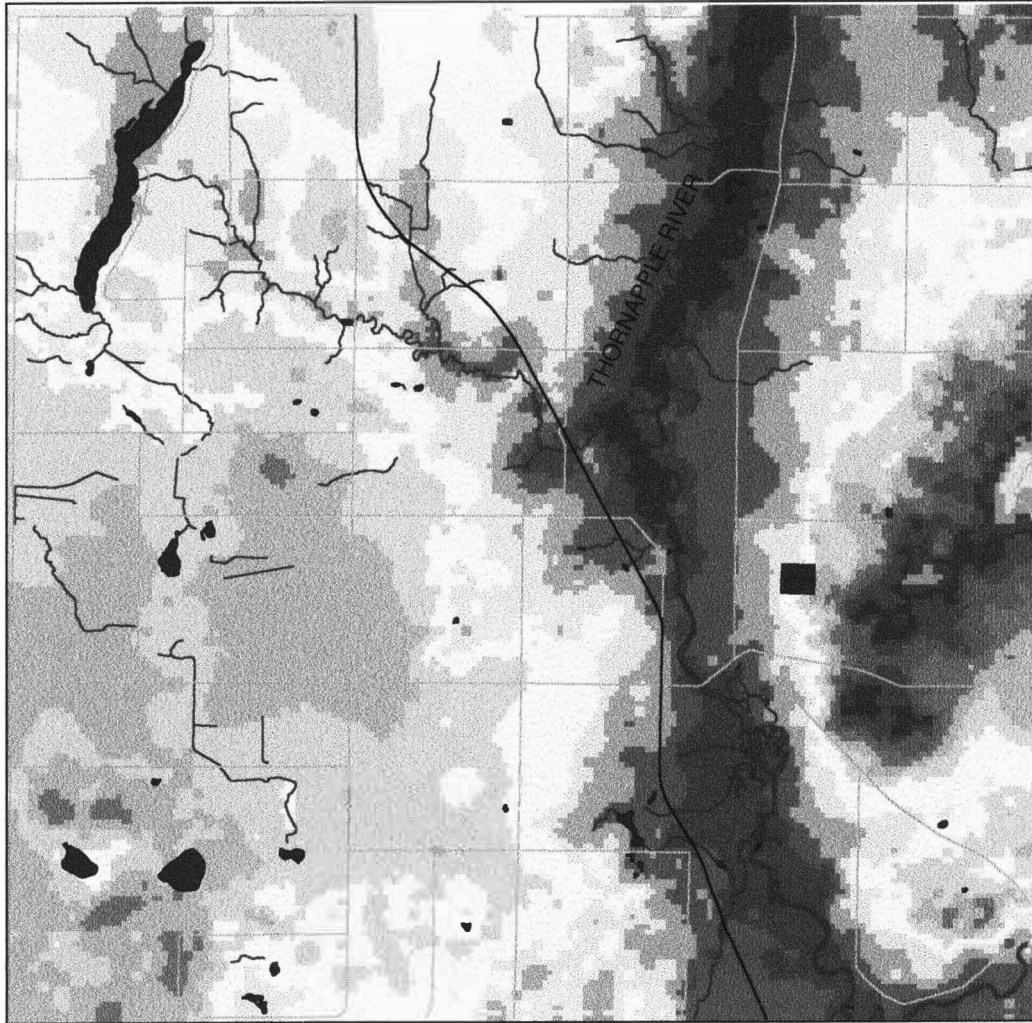
Poor Excellent
 1 2 3 4 5




















Serious limitations:

Appendix D
Hardcopy Output for Computerized GIS

ArcView

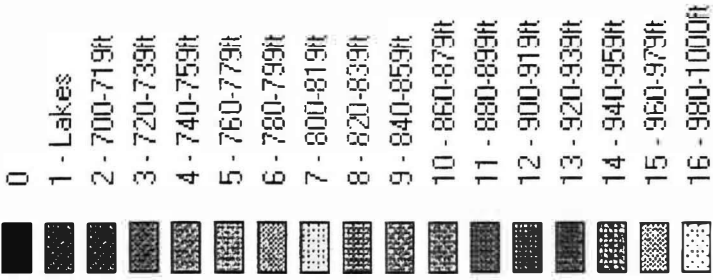
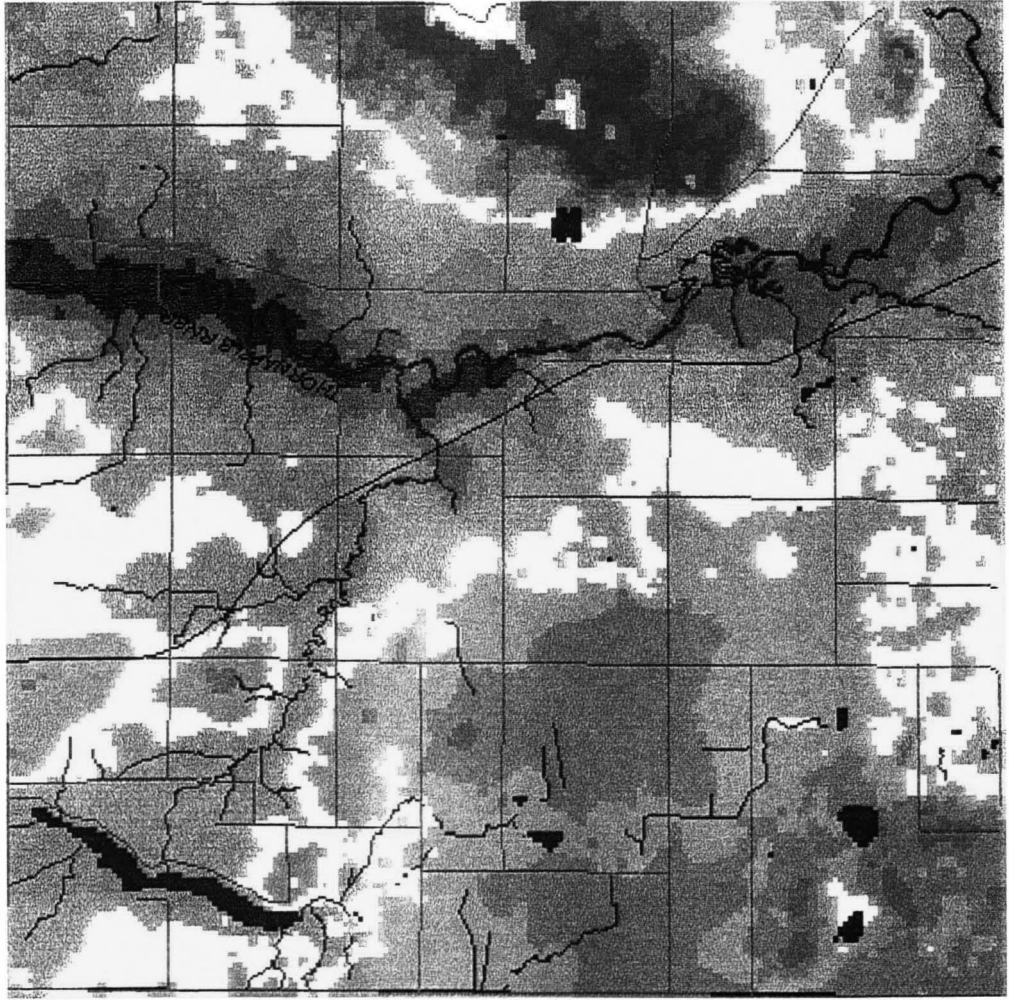
THORNAPPLE TOWNSHIP



-  HIGHWAY
-  ROADS
-  RIVERS
-  LAKES
- ELEVATION
-  700
-  720
-  740
-  760
-  780
-  800
-  820
-  840
-  860
-  880
-  900
-  920
-  940
-  960
-  980

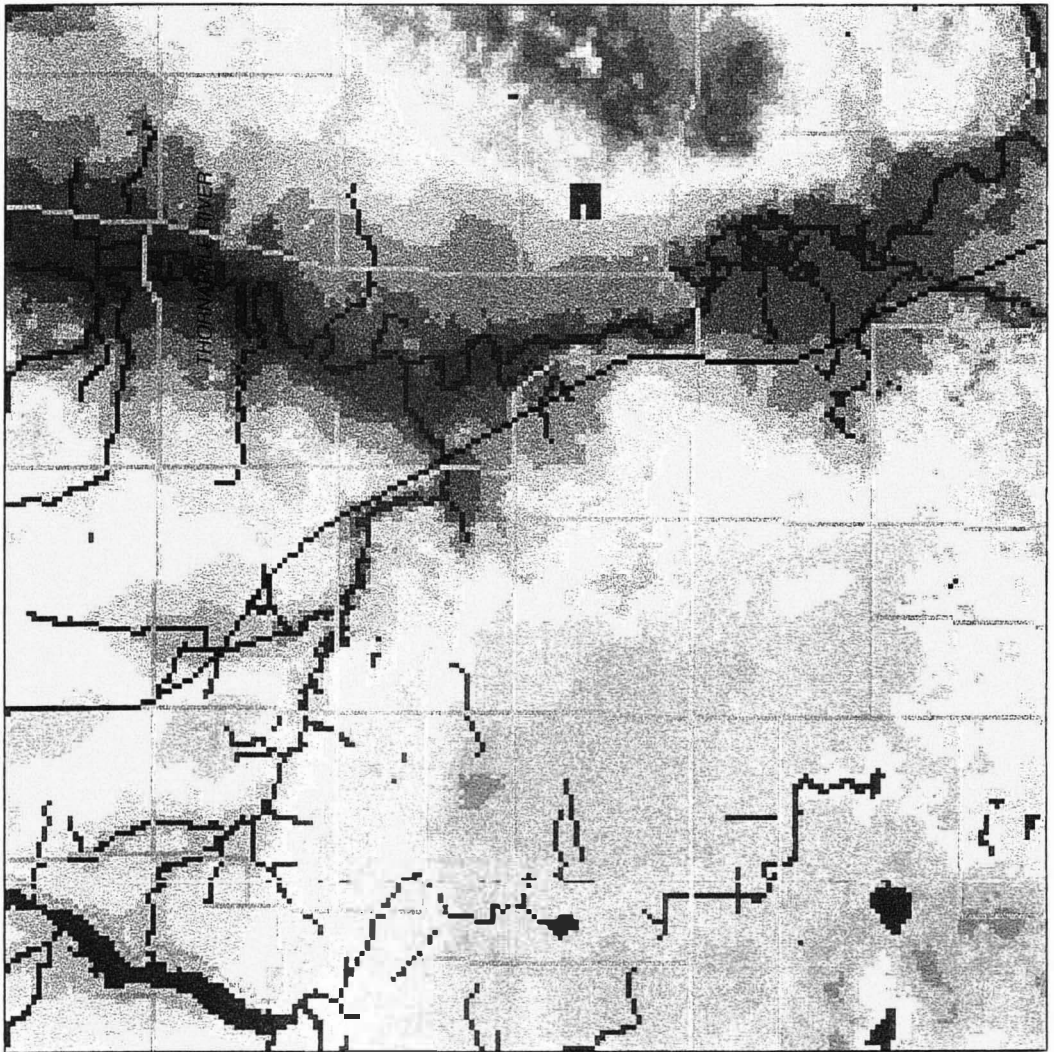
THORNAPPLE TOWNSHIP

IDRISI

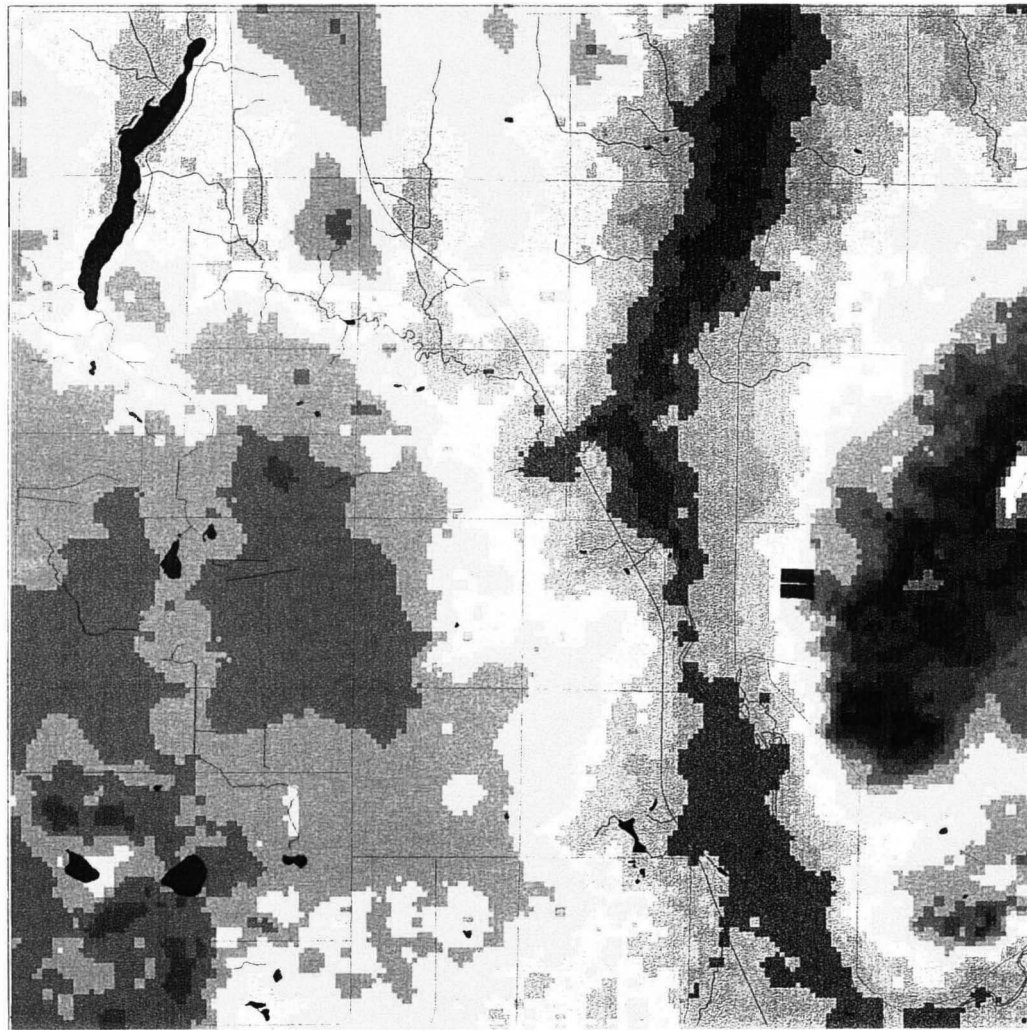


THORNAPPLE TOWNSHIP

Map Factory



- Lakes
- Rivers
- Roads
- Highway
- 700-719 ft
- 720-739 ft
- 740-759 ft
- 760-779 ft
- 780-799 ft
- 800-819 ft
- 820-839 ft
- 840-859 ft
- 860-879 ft
- 880-899 ft
- 900-919 ft
- 920-939 ft
- 940-959 ft
- 960-979 ft
- 980-999 ft



ELEVATION

- 700 feet
- 720 feet
- 740 feet
- 760 feet
- 780 feet
- 800 feet
- 820 feet
- 840 feet
- 860 feet
- 880 feet
- 900 feet
- 920 feet
- 940 feet
- 960 feet
- 980 feet
- Lakes
- Rivers
- Roads
- Highway

Appendix E

Protocol Clearance From the Human Subjects
Institutional Review Board

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899
616 387-8293

 WESTERN MICHIGAN UNIVERSITY

Date: March 8, 1996

To: C. Sonia Wardley

From: Richard Wright, Chair

Re: HSIRB Project Number 96-03-02

This letter will serve as confirmation that your research project entitled "The potential role of geographical information systems in high school geography education in the Kalamazoo Valley and Calhoun County Intermediate School Districts" has been **approved** under the **exempt** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: March 8, 1997

xc: Joseph Stoltman, GEOG

Appendix F
Demonstration Materials for Student Recruitment

STUDENT RECRUITMENT

Three problem scenarios were outlined to the students and solved as described below:

1. Biodiversity Park. You are the GIS specialist with the Michigan Department of Natural Resources (DNR). Michigan wishes to develop a State park which will demonstrate the advantages of biodiversity. There are three requirements: (1) the area must have as much biodiversity of habitat as possible, (2) the park must be over 60 square miles in area, and (3) the park must be on State or Federal lands. You have 4 maps of Michigan which you can use: Landcover of Michigan, Forests of Michigan, Rivers, and Administrative Units of Michigan. The procedure to solve this problem would be as follows: (a) combine the Landcover, Forest, and Rivers map layers to form a habitat map, (b) find areas of greatest biodiversity, (c) group these to find the contiguous areas of over 60 square miles, and (d) find where these areas of greatest biodiversity are on State or Federal lands. This would only be a starting point. Biologists and natural resource experts would have to survey each possible site to catalogue the present flora and fauna populations, to determine the optimum size of the park, and the logistics of dealing with large numbers of people visiting to the park. The County Roads map layer could be added to the final map to study accessibility to possible sites (Figure 32).

2. Regional Sales Office Sites. You work for a company which is expanding rapidly and needs to find new sites for regional sales offices and distribution centers. The sales manager has determined the requirements for possible sites: (1) they should be within 7 miles of a city, so there will be an available labor supply, (2) they should not be within the city limits as land prices may be too high as a large area of land will be

needed, and (3) the present landuse should be agricultural, range, or barren land as rezoning of these landuses may be more feasible. You have 2 maps of Michigan which you can use: Landcover of Michigan and Cities. The procedure to solve this problem would be as follows: (a) draw 7 mile buffers around each city, (b) find areas of acceptable landuse (agricultural, range or barren land), and (c) find where there is acceptable land within the 7 mile buffers around the cities. These would be possible sites for regional sales offices. This again would be only a starting point. The next stage would be to look at communications and possible sales regions (Figure 33).

3. Most Cost Effective Route for a New Power line. You work for a utility company in the northern Lower Peninsula. Roscommon is a small but expanding community near Cadillac, which needs a new power source. This will come from Cadillac. You will use a GIS to determine the most cost effective route for the new power line. You will assume: (1) the least expensive route would be over agricultural, range, and barren lands, (2) it is more expensive to go through forest, since it has to be cleared, however deciduous trees provide more valuable wood than coniferous trees, and (3) routes through urban areas, over wetlands, and lakes are too expensive and may be prohibited by legislation. You have 2 maps of Michigan which you can use: Landcover for Michigan and Cities from which you subset out the area under study. The procedure to solve this problem would be as follows: (a) determine appropriate weightings for the various landuses, (b) construct a cost surface from Cadillac, and (c) find the most cost efficient route from Cadillac to Roscommon (Figure 34).

The procedures for solving these problems as outlined above could not be demonstrated in real time as this would take too long. The map files were exported out of ERDAS and imported into IDRISI using the ERDIDRISI module. Maps were prepared to illustrate each of the principal stages of the problem solution. These were exported using ERDIDRISI as ERDAS files and imported into ArcView for the

demonstration. Here, with the judicious use of color and transparent backgrounds, it was possible to overlay the map layers to simulate the problem solving process in a matter of minutes, for each of the scenarios.

Biodiversity Park

Problem: Identification of areas, over 100 sq. km. in size, on State and Federal lands, showing greatest biodiversity.

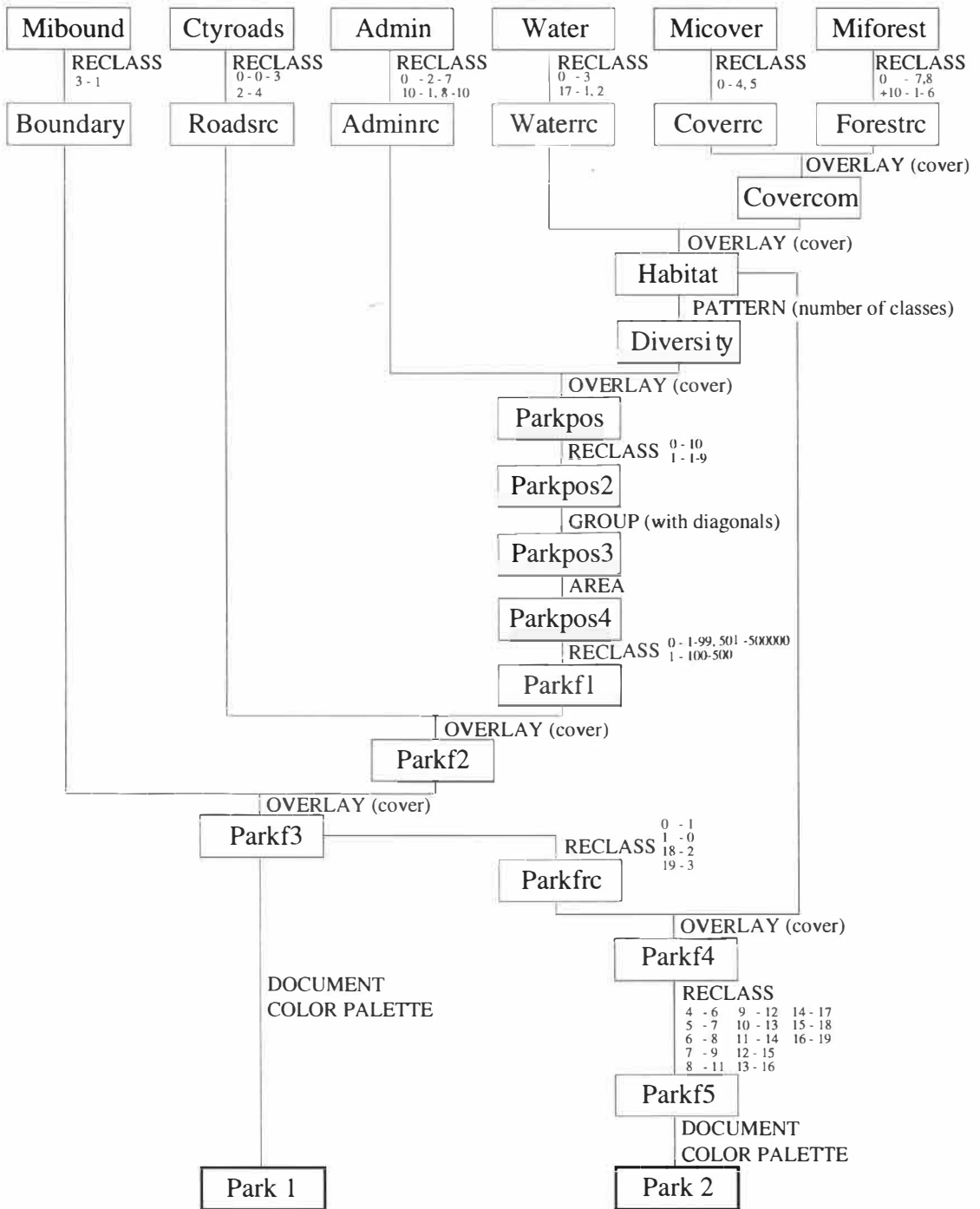


Figure 32. Biodiversity Park—Problem Solving Methodology.

Commercial Site Selection

Problem: Possible sites for regional sales and distribution centers in Michigan.
 Requirements: Sites outside city limits, but under 10 km of large cities (over 15 sq.km.). Present landuse—agricultural land, rangeland, or barren land.

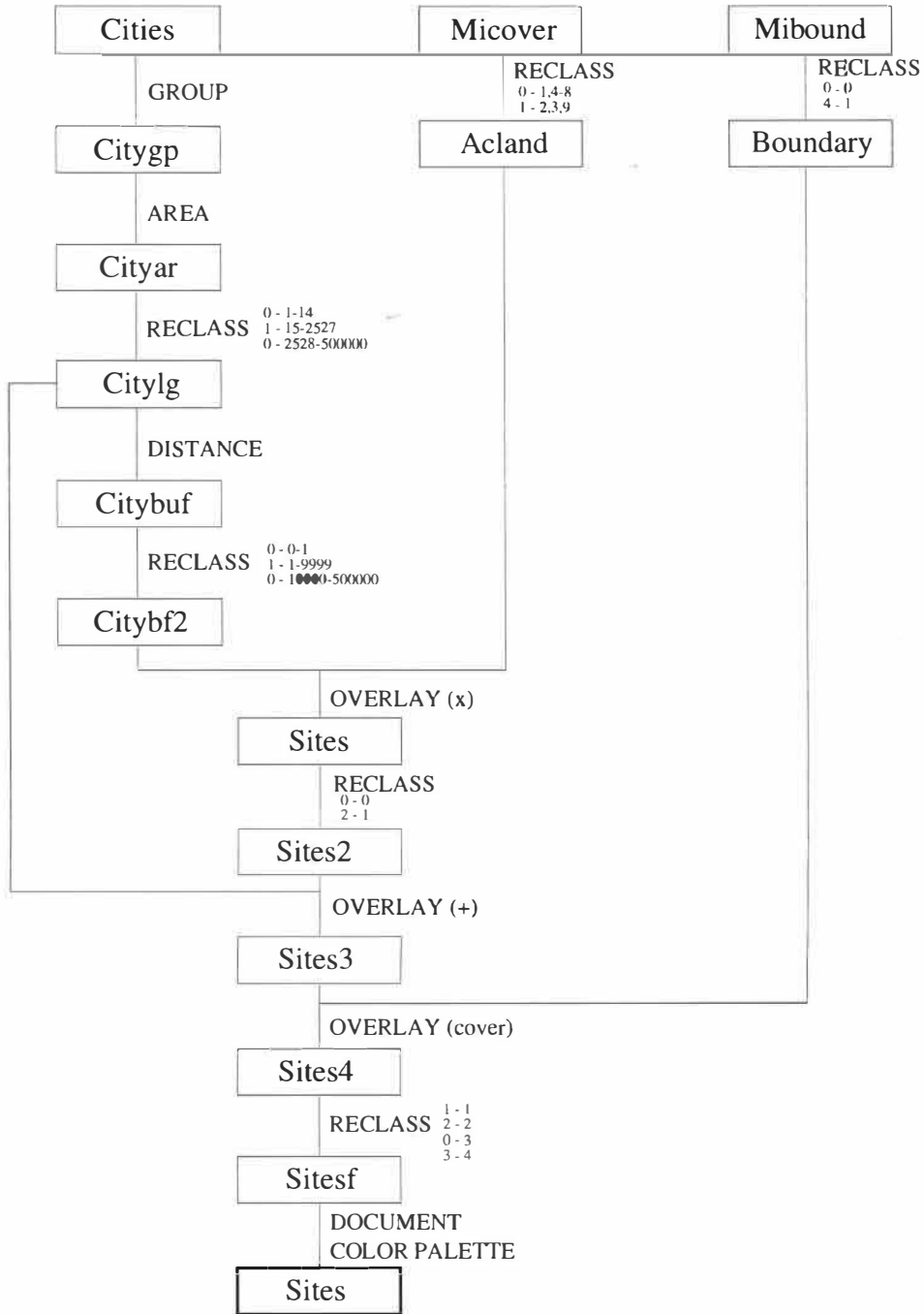
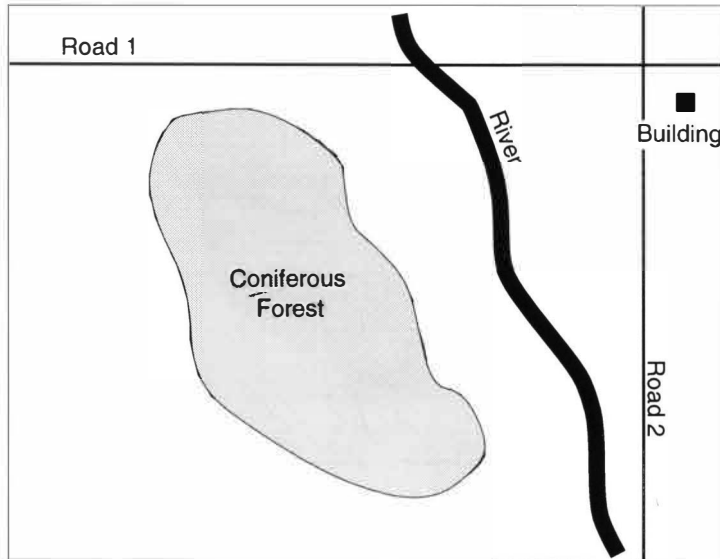


Figure 33. Commercial Site Selection—Problem Solving Methodology.

Appendix G
Materials for the Student Evaluation

INTRODUCTION TO GIS

Vector System



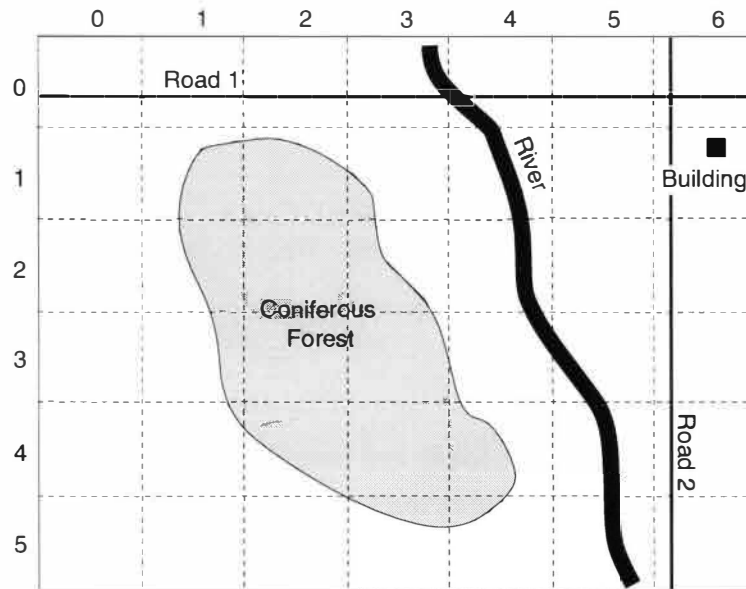
A vector system can show 3 types of features:

- Points, e.g., well site
- Lines, e.g., railroad
- Polygons, e.g., area of forest

There are 5 features on the map: one point feature, three line features, and one polygon feature. Take each one and on the table below enter its Feature Type (point, line, or polygon), give it a unique number as an Object ID, and give it an Attribute (what is it?). One is done for you.

| Feature Type | Object ID | Attribute |
|---------------------|------------------|------------------|
| Point | 1 | Building |
| | | |
| | | |
| | | |
| | | |

Raster System



The raster system shows all features in the same way, as pixels (cells or squares). Each pixel is given a code number to signify what it represents, e.g., coniferous forest—code 1, deciduous forest—code 2.

There are 5 features on the map. ON THE MAP write in the code for each pixel to show which feature it represents.

In this example give:

- Background—code 0
- Coniferous Forest—code 1
- Roads—code 2
- River—code 3
- Building—code 4

When complete, enter the code given to each of the pixels listed in the table. To find the pixel number “read right, then down,” e.g., the building is in pixel number: 6.1.

| Pixel Number | Code |
|--------------|------|
| 0.0 | 2 |
| 0.1 | |
| 2.2 | |
| 2.4 | |
| 4.5 | |
| 6.1 | |
| 4.3 | |

INSTRUCTIONS FOR EXERCISES—FIRST SET.

Group: _____

Time: Start _____

Finish _____

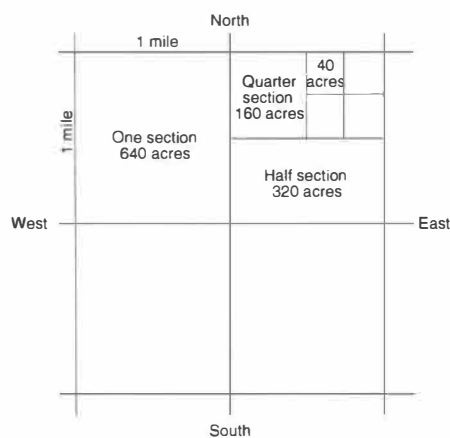
ARCVIEW (BLUE—1)

This GIS requires vector (lines) maps. It can display raster maps, but they can not be queried or analyzed.

In this program maps are called **Themes** and all the maps (themes) which you will need are organized into a **Project** called **Thornapple.apr**. Within this project the maps (themes) are further grouped into 2 **Views** called Exercise 1 and Exercise 2.

Exercise 1

Concept: Human and environmental interaction. One way in which the environment affects human activity can be seen in the rectangular survey system, which was used to divide the land in many states including Michigan. The surveyors measured the land into one mile square sections. Each six by six mile block of land (36 sections) was called a township. Settlers bought 40 acres, quarter sections, or half sections of land to farm (see below).



Rectangular Survey

Research Question: How did the environment affect the rectangular survey in Thornapple Township? Thornapple Township is in north west Barry County, about half way between Hastings and Grand Rapids.

To begin:

Make sure the Thornapple.apr Project box is visible on the screen.

(If not: Go to File -> Open Project

Select Thornapple folder

Scroll down and choose Thornapple.apr

Click Open.)

Thornapple.apr Project box contains all the maps needed for Exercise 1 and 2.

Click on Exercise 1 - it will be highlighted in black.

Click Open.

The elevation of Thornapple Township will be displayed.

IF THIS DOES NOT APPEAR OR IT HAS OTHER LAYERS SHOWING AS WELL ASK FOR HELP.

A displayed map is called a **Theme** and the list of other maps available in that **View** (Exercise 1), along with their legends, are displayed on the left hand side of the map. This list is called the **Table of Content**.

The map which is displayed shows how the height of the land varies throughout Thornapple Township. The legend shows which color represents which height. For instance the darkest green is used to represent all heights from 700 to 719 feet. Since it is difficult to distinguish some of the colors on the map, explore the map using the Information Tool.

Make sure the map is selected by clicking BY the legend of ELEVATION, so that it appears raised. That means there is a fine gray line above and below the ELEVATION legend. This means it is selected.

Click on the Information Tool (1st button on second row of tool bar) (i).

The cursor will become crosshairs as you move it across the map.

Click anywhere on the map. The height at that point is shown in an Identify Results box in the middle of the screen.

Move the box to the lower left of the screen by click and dragging on top bar.

Double click on the map to find another height.

Describe where the lowest elevation on the map is located. (The map is aligned conventionally with north at the top of the screen.)

Describe where the highest elevation on the map is located.

Try to get some idea of the shape of the land.

Close the Identify Results box by clicking on the square in the upper left hand corner of the box.

To close ELEVATION - click on the √ in the small box to the left of the word ELEVATION in the Table of Content (the list on the left). The √ and map disappear.

Now look at the hydrology (lakes and rivers).

To open LAKES click on the small box to left of LAKES in the Table of Content, √ and map appears.

The map which is displayed shows lakes in Thornapple Township.

Look at their sizes and distribution.

Overlay the rivers.

To open RIVERS click on the small box to left of RIVERS in the Table of Content, √ and map appears.

This shows the drainage pattern. The area is drained by the Thornapple River and its tributaries.

Now look at the hydrology and the elevation together.

To open ELEVATION click on the small box to left of ELEVATION in the Table of Content, ✓ and map appears.

However it has obscured the hydrology. The order of maps in the Table of Content is important. ELEVATION contains no transparent portions, therefore it has to be drawn first and the other layers drawn on top of it. The maps in the Table of Content are drawn in order from the bottom of the list up, therefore you have to move ELEVATION to the bottom of the list.

To do this, click BY the legend of ELEVATION to select it, then click and drag the legend to the bottom of the list in the Table of Content. The map will be displayed first and LAKES and RIVERS on top of it.

You can see all the lakes and rivers as well as the elevation.

What is the elevation of the large lake in the north west?

Close the Identify Results box if you used it, by double clicking on the square in the upper left hand corner.

This is the environment in which the surveyors had to work when they laid out the rectangular survey system. You can see evidence of their work in the road pattern. Overlay the layer ROADS on your map.

To open ROADS click on the small box to left of ROADS in the Table of Content, ✓ and map appears.

Look carefully at the map.

Describe where on the map the rectangular survey is most obvious.

To close this exercise, click on the ✓ by ROADS, RIVERS AND LAKES to close them.

Keep ELEVATION open and make sure it is selected. Move ELEVATION to the top of the list again by clicking and dragging legend to top of the Table of Content.

Close Exercise 1 by clicking on small box in top left corner of MAP window.

Exercise 2

Concept: Human and environmental interaction. Here you will look this concept from the opposite perspective. How do people impact the environment. Wetlands are now considered vital to the health of the ecosystem. However they are increasingly under threat from residential and industrial development.

Research Question: Are urban developments encroaching on wetlands in Thornapple Township?

Begin by looking at the landuse in Thornapple Township.

Click on Exercise 2 in the Project box for Thornapple.apr. - highlighted black.

Click Open.

This will open Exercise 2 - This contains all the maps needed for Exercise 2.

A new map will be displayed. This is a landuse map which shows how land is used in Thornapple Township.

IF THIS DOES NOT APPEAR OR IT HAS OTHER LAYERS SHOWING AS WELL ASK FOR HELP.

The legend shows which colors represents which landuse codes. Landuse codes are used to classify the different types of landuse.

Explore the map using the Information Tool.

Make sure the map is selected by clicking BY the legend of LANDUSE, so that it appears raised. That is there is a fine gray line above and below the LANDUSE legend.

This means it is selected.

Click on the Information Tool (1st button on second row of tool bar) (i).

The cursor will become crosshairs as you move it across the map.

Click anywhere on the map. The landuse code and its description at that point are shown in the Identify Results box. You may have to enlarge the box to see the whole description.

Move the box to the lower left of the screen by click and dragging on top bar, so that you can see as much of the map as possible.

Double click on the map to find another landuse.

Which landuse covers the largest area? (Give the code and the description.)

Close Identify Results box by double clicking on the square in the upper left hand corner.

Even with the Information Tool it is difficult to distinguish landuse patterns. Therefore you will now direct the computer to select and show some features on their own. This is called “querying.”

You will direct the computer to show all the areas of wetlands and then all the areas of residential, commercial, and industrial development. Then you will direct the computer to show where there are areas of residential, commercial, and industrial development within 500 feet of wetlands. These are the areas which may be encroaching upon and endangering the wetlands.

However first you will need to determine which codes are used for these landuses.

If necessary move map to right by clicking and dragging on the top bar, so that you can see the Project box for Thornapple.apr.

Double click on Tables (2nd icon down) in Project box.

Choose CODES.DBF by clicking on it - it will be highlighted in black.

Click Open.

Scroll through the table.

Which range of codes denotes residential, commercial, and industrial use?

Which range of codes denotes wetlands? _____

Close Table by double clicking on the square in the upper left hand corner.

Click on Views (1st icon) to return to the map.

Click on the map to make it active - top bar becomes striped.

Move map to left so that it is all visible.

To query you have to direct the computer where to look for the features you want to see.

Make sure LANDUSE is selected. (Click BY legend of LANDUSE, so that it appears raised.)

Now you will direct the computer to choose all the areas that have a coding for wetlands, that is a code of 611 and above.

Go to Theme -> Properties.

Properties box opens.

Under *Definition* click on Query Builder button (hammer and ?).

Query Builder box opens.

Here you have to place the statement which tells the computer exactly what to do. It is therefore very important to get the wording exactly right! So follow the directions carefully.

Under *Fields*.

Double click on Landuse Code (that is the column in which the landuse codes are listed).

The word "Landuse Code" will appear in the box.

Click on >= (greater than or equals) - this will appear in box.

Under *Values* scroll down and double click on 611.

The Query should read:

([Landuse Code] >= 611)

Click on OK.

Click on OK in Theme Properties box.

The progress of the procedure is shown by the blue line under the Tool Bar.

All the wetlands will be displayed.

This map has to be converted into a file so that you can keep it to work on.

Go to Theme -> Convert to Shapefile.

Under *Convert LANDUSE*, in box

Type in name: WETLANDS.shp

Click Save.

Click on "Yes" to question "Add Shapefile as a theme to a view?"

When asked “*Add theme to:*”

Click on “Exercise 2” (highlighted in black.)

Click OK.

WETLANDS.shp is now added to the Table of Content.

Although the Wetlands appears to be displayed, this is not the new file, only the selected areas on the LANDUSE map. To display the new map, click on the \surd by LANDUSE to remove it, then click on the box by WETLANDS.shp so that \surd and the map appear.

You will now color the wetlands an appropriate color.

First you need to make the layer selectable.

Click By the legend of WETLANDS.shp, so that it appears raised.

Double click on the colored legend box under WETLANDS.shp in the Table of Content.

Legend Editor opens.

Double click on the colored box in the table section below the word: “*Symbols.*”

Fill Palette box opens. Make sure there is a black line around the solid black square. If not click on it.

Click on the button with the colored paintbrush (5th from left at top of Fill Palette box).

Color Palette opens.

Choose a bright shade of turquoise by clicking on a colored square.

Close Color Palette by clicking on square in top left of Palette.

The box should now be turquoise (the box in the table section below the word: “*Symbols.*”)

Click on Apply.

The legend box in the Table of Content should now be turquoise.

Close the Legend Editor by clicking on square in top left.

Wetlands should be colored turquoise.

Look carefully at the distribution of wetlands.

To check that only wetlands are shown, click on Table button on tool bar (5th from left on top bar).

Scroll quickly through the table. Check only wetlands are shown.

How many wetlands are there in Thornapple Township? (Look at the line beneath the tool bar - this will tell you how many polygons are wetlands.)

Close Table by clicking on the square in the upper left hand corner.

Click on \surd by WETLANDS.shp to remove map.

Click on box to left of LANDUSE to display original map. \surd and map will appear, however it will show the selected wetlands not the total landuse.

To return the LANDUSE map to its original form:

Select LANDUSE by clicking BY legend so that it appears raised.

Go to Theme -> Properties.

Click on CLEAR to remove query statement.

Click OK.

The original landuse map will be displayed.

To find all the residential, commercial, and industrial areas (they are called urban from now on), you will direct the computer to find all the areas with a coding of 130 or less. (Communication, utilities, open-pit extractive, and cemeteries are excluded here for simplicity.)

Go to Theme -> Properties.

Properties box opens.

Under *Definition* click on Query Builder button (hammer and ?).

Query Builder box opens.

Here you have to place the statement which tells the computer exactly what to do. It is therefore very important to get the wording exactly right! So follow the directions carefully.

Under *Fields*.

Double click on Landuse Code (that is the column in which the landuse codes are listed).

The word "Landuse Code" will appear in the box.

Click on <= (less than or equals) - this will appear in box.

Under *Values* double click on 130.

The Query should read:

([Landuse Code] <= 130)

Click on OK.

Click on OK in Theme Properties box.

All the urban areas will be displayed.

This map has to be converted into a file so that you can keep it to work on.

Go to Theme -> Convert to Shapefile.

Under *Convert LANDUSE*, in box

Type in name: URBAN.shp

Click Save.

Click on “Yes” to question “*Add Shapefile as a theme to a view?*”

When asked “*Add theme to:*”

Click on “Exercise 2” (highlighted in black).

Click OK.

URBAN.shp is now added to the Table of Content.

Although the URBAN appears to be displayed, this is not the new file, only the selected areas on the LANDUSE map. To display the new map, click on the by LANDUSE to remove it, then click on the box by URBAN.shp so that and the map appear.

You will now color the urban areas an appropriate color.

First you need to make the layer selectable.

Click BY legend of URBAN.shp, so that it appears raised.

Double click on the colored legend box under URBAN.shp in the Table of Content.

Legend Editor opens.

Double click on the colored box in the table section below the word: “*Symbols.*”

Fill Palette box opens. Make sure there is a black line around the solid black square.

Click on the button with the colored paintbrush (5th from left at top of Fill Palette box).

Color Palette opens.

Choose a bright yellow by clicking on a colored square.

Close Color Palette by clicking on square in top left of Palette.

The box should now be yellow (the box in the table section below the word: “*Symbols.*”)

Click on Apply.

The legend box in the Table of Content should now be yellow.

Close the Legend Editor by clicking on square in top left.

Urban should be colored yellow.

Look carefully at the distribution of urban areas.

To check that only urban polygons are shown, click on Table button on tool bar (5th from left on top bar).

Scroll quickly through the table. Check only urban landuses are shown.

How many urban landuse polygons are there in Thornapple Township? (Look at the line beneath the tool bar - this will tell you how many polygons are urban.)

Close Table by clicking on the square in the upper left hand corner.

Click on by URBAN.shp to remove map.

Click on box to left of LANDUSE to display original map. and map showing selected urban areas not the total landuse map will appear.

To return LANDUSE map to its original form:

Select LANDUSE by clicking BY legend so that it appears raised.

Go to Theme -> Properties.

Click on CLEAR to remove query statement.

Click OK.

The original landuse map will be displayed.

To display the wetlands and urban areas together:

Click on by LANDUSE to remove this map.

Click in the boxes to the left of the WETLANDS.shp and URBAN.shp maps so that appears. The maps will appear overlaid.

Although you can now clearly see all the wetlands and all the urban areas, it is still difficult to see every place where they are in close proximity.

You will now direct the computer to answer the question: “Which urban areas are within 500 feet of wetlands?”

You will do this by directing the computer to create 500 foot buffer zones (or circles) around each wetland and then to find which urban areas fall within these buffer zones.

This next step is tricky, so make sure you follow the instructions precisely. Make sure that URBAN.shp is selected by clicking BY legend, so that it appears raised. It is now active.

Go to -> Theme ->Select by Theme ...

Enter the following:

Select features of active themes that: Scroll down and select “Are Within Distance Of”

the selected features of: Scroll down and select WETLANDS.shp

Selected Distance: type 500

Click *New Set*.

The map displayed will show no buffer zones, but the urban areas within 500 feet of a wetland are highlighted in red. The other urban areas are still yellow and the wetlands are all turquoise.

To enlarge an area click on Zoom-in Tool on tool bar (4th from left).

Click on center of map - it will enlarge with each click.

Click on Grabber Tool on tool bar (6th from left).

Click and drag to move the map around so that you can inspect other areas.

NOTICE that the whole polygon is highlighted even when only a small part of it is within 500 feet of a wetland.

Is it possible to see which areas are within the 500 foot buffer zone? Explain your answer.

Use the Zoom-out Tool (5th from left right) to return map to original size, reposition it with Grabber Tool (6th from left).

Overlay the Roads on the map.

To overlay ROADS click on the small box to left of ROADS in the Table of Content, ✓ and map appears.

Overlay the main Grand Rapids-Hastings HIGHWAY in the same way.

How would you describe the distribution of the wetlands most under threat from urban expansion?

Does this GIS give you an accurate picture of which wetlands are most under threat? Explain your answer.

Close ROADS, and HIGHWAY, by clicking on the ✓ marks.

Select URBAN.shp (so that it is raised), go to Edit -> Delete Themes.

Select WETLANDS.shp (so that it is raised), go to Edit -> Delete Themes.

Open LANDUSE and select (so that it is raised).

Go to File -> Close All.

Now please could **each** student fill in a questionnaire on this GIS.

Group: _____ Student A:

ARCVIEW (BLUE)

What did you like about the way this GIS performed the overlays in Exercise 1?

What did you dislike about the way this GIS performed the overlays in Exercise 1?

What did you like about the way this GIS performed the analysis in Exercise 2?

What did you dislike about the way this GIS performed the analysis in Exercise 2?

How well did this GIS define (show) the endangered wetlands in Exercise 2?

FINISHED

Return these instructions to the front desk.

While you take a break discuss what you have just done. What did you like and dislike about this GIS? How effective was it at helping you solve the research questions?

Remember you will be asked to rank and comment on this GIS program at the end of the session.

INSTRUCTIONS FOR EXERCISES—SECOND SET.

Group: _____

Time: Start _____

Finish _____

IDRISI (GREEN—2)

This GIS can display both raster (pixel) and vector (lines) maps, but can only analyze raster maps. The raster maps are called **image files** and the vector maps are called **vector files**.

Exercise 1

Concept: Human and environmental interaction.

Research Question: How did the environment affect the rectangular survey in Thornapple Township? Thornapple Township is in north west Barry County, about half way between Hastings and Grand Rapids.

To begin:

Go to menu Environment -> Environ

Check you are in correct directory (Top box).

Path of working data directory: c:\idrisi\thornapp\ex1

(If not: in large central box:

under *Drive:* select c:\

under *Directory* double click on c:\

scroll and double click on idrisisw

double click on thornapp

double click on ex1

Make sure *Path of working data directory:* reads c:\idrisi\thornapp\ex1.)

Click OK.

To display the first map:

Go to menu Display -> Display Launcher.

Enter the following:

Type of file: image file (this is raster).

Name of file to display: double click on empty box

Click on ELEV on list (this will highlight it in blue)

Click OK.

Map Components: click on legend (x appears in box).

Palette options (these are the colors): double click on *User Defined* empty box

Click on ELEV on list (this will highlight it in blue)

Click OK.

Click OK.

The elevation of Thornapple Township will be displayed.

IF THIS DOES NOT APPEAR ASK FOR HELP.

The legend shows which color represents which height.

What is the range of codes? _____

Explore the map using the information Tool.

Click on the Information Tool (↓?) on the tool bar (7th from left).

The cursor will become crosshairs as you move it across the map.

Click anywhere on the map. The code at that point is shown at the bottom right of the screen: the z: is the code. The corresponding height is given in the legend.

As you move the crosshairs across the map the column (c) and row (r) numbers of the pixels and the x and y coordinates change in the boxes at the bottom of the screen.

Move the crosshairs about until: x = 1700338.0 and y =442787.6, then carefully click.

What is the height of the land at these map coordinates?

Close this map. Double click on small box in top left corner of the MAP window.

Now look at the hydrology (lakes and rivers).

Go to menu Display -> Display Launcher (or 4th from left on tool bar - world map).

Enter the following:

Type of file: image file (this is raster).

Name of file to display: double click on empty box

Click on LAKES on list (this will highlight it in blue)

Click OK.

Map Components: click on legend (x appears in box).

Palette options: double click on User Defined empty box

Click on LAKES on list (this will highlight it in blue)

Click OK.

Click OK.

Notice that the background is white and in the legend it is classified as zero - this means that it is transparent. The LAKES are classified as 1. This becomes important later. Now we can overlay the RIVERS. This is a vector layer (lines as opposed to pixels) so it can be displayed directly on top of the LAKES.

To the right of your map there is a tool box called Composer this shows which maps are being displayed, in this case LAKES.

Click on *Add Layer* in Composer.

Enter the following:

Vector file to display: double click on empty box

Click on RIVERS to highlight

Click OK.

Symbol file (this is the colors): double click on User Defined empty box

Click on RIVERS to highlight

Click OK.

Click OK on original Add Layer box.

Look at how the land is drained.

Do you notice anything unusual about the drainage in the SW quarter of the map?

Suggest a reason for this pattern.

Close this map. Double click on small box in top left corner of the MAP window.

Now look at the hydrology and the elevation together.

Since LAKES and ELEV are both raster maps you have to use an overlay procedure.

Go to: Analysis -> Database Query -> OVERLAY.

Here you choose a first map to overlay over a second map.

Remember how on the LAKES map lakes were classified as 1 and the background was classified as zero, which is transparent. The ELEV was classified from 2 to 16.

Therefore if we overlay LAKES over the ELEV the lakes (1) will show on top and the elevation (2-16) will show through the transparent background of LAKES. The top map must have transparent background and all the codes must be different if they are to be seen as separate features after overlay.

Therefore enter the following:

First Image: double click on empty box

Click on LAKES to highlight (or double click)

Click OK.

Second Image: double click on empty box

Click on ELEV to highlight (or double click)

Click OK.

Output Image: Click to place cursor in box then type on keyboard: ENVIRON.

Overlay options: Click on last one - First covers Second except where zero.

Click OK.

A blue line in bottom left box of screen will show the progress of this overlay procedure. When complete you can display the map you have created.

Go to Display -> Display Launcher.

Enter the following:

Type of file: image file (this is raster).

Name of file to display: double click on empty box

Click on ENVIRON to highlight (or double click)

Click OK.

Map Components: click on legend (x appears in box).

Palette options: double click on User Defined empty box

Click on ENVIRON to highlight (or double click)

Click OK.

Click OK.

A new map will be displayed. You can see all the lakes (1) as well as the elevation (2-16). You may have to scroll through the legend to see it all.

Add the RIVERS (vector).

Go to Composer (to the right of your map).

Click on *Add Layer*.

Enter the following:

Vector file to display: double click on empty box

Click on RIVERS to highlight (or double click)

Click OK.

Symbol file (this is the colors): double click on User Defined empty box

Click on RIVERS to highlight (or double click)

Click OK.

Click OK on original Add Layer box.

Look carefully at the map.

Which part of the principal river valley do you think is most prone to flooding?

What map evidence did you use to determine this?

Add the vector layer ROADS to your map.

Go to Composer (to the right of your map).

Click on *Add Layer*.

Enter the following:

Vector file to display: double click on empty box

Click on ROADS to highlight (or double click)

Click OK.

Symbol file : double click on User Defined empty box

Click on ROADS to highlight (or double click)

Click OK.

Click OK on original Add Layer box.

Look carefully at the map. Although there is plenty of evidence of the rectangular survey system in the road pattern, there are deviations.

Describe any deviations you can see on the eastern half of the map.

What has caused these do you think from the map evidence?

To close this exercise, double click on small box in top left corner of the MAP window for each map.

Exercise 2

Concept: Human and environmental interaction.

Research Question: Are urban developments encroaching on wetlands in Thornapple Township?

To open landuse in Thornapple Township:

Go to Environment -> Environ (or 1st from left on tool bar).

In large central box : double click on thornapp

Double click on ex2

Check the top box it should read: c:\idrisiw\thornapp\ex2

Click OK.

To display LANDUSE in Thornapple Township:

Go to Display -> Display Launcher.

Enter the following:

Type of file: image file (raster).

Name of file to display: double click on empty box

Click on LANDUSE on list

Click OK.

Map Components: click on legend (x appears in box).

Palette options: double click on User Defined empty box

Click on LANDUSE on list

Click OK.

Click OK.

IF THIS DOES NOT APPEAR ASK FOR HELP.

Enlarge the legend window by double clicking on legend, red dots appear at edges.

Place the cursor on the dot on the bottom edge, it becomes a double arrow, then click and drag, until the legend is tall as possible. You will still have to use the scroll bar to see all of it. Do the same to widen the legend window.

The legend shows which colors represents which landuse, followed by the code, then a description of the landuse.

Explore the map using the Information Tool.

Click on the Information Tool on the tool bar (↓?) (7th from left).

The cursor will become crosshairs as you move it across the map.

Click anywhere on the map. The code at that point is shown at the bottom right of the screen: the z: is the code. The corresponding landuse description is given in the legend.

What is the complex red and orange area to the lower right of center?

You will now direct the computer to select all the areas of wetlands and then all the areas of residential, commercial, and industrial development. However first you will need to determine which codes are used for these landuses.

Scroll down through the legend and find:

Which range of codes denotes residential, commercial, and industrial use?

Which range of codes denotes wetlands? _____

To perform this query you have to reclassify the map codes so that only the ones you want to see will be displayed. Therefore you will recode all the landuse codes other than wetlands (0 to 26) to zero (transparent) and the wetlands codes (27 to 30) to 1.

Go to Analysis -> Database Query -> RECLASS

Enter the following:

Type of file to reclass: image.

Classification type: used defined reclass.

Input file: double click on empty box

Click on LANDUSE on list

Click OK.

Output file: click and type on keyboard: WETLANDS

Assign a new value of: click and type 0

To all values from: click and type 0

To just less than: click and type 27

Click on right hand arrow to enter next code - check it reads 2 beneath the arrows. If it read anything more, use the left arrow to get back to 2. **YOU MUST NOT HAVE ANY BLANK CLASSES.**

Assign a new value of: click and type 1

To all values from: click and type 27

To just less than: click and type 31

Click OK.

To display Wetlands:

Go to Display -> Display Launcher.

Enter the following:

Type of file: image file (raster).

Name of file to display: double click on empty box

Click on WETLANDS on list

Click OK.

Map Components: click on legend (x appears in box).

Palette options: click on QUALITATIVE 16.

Click OK.

Look carefully at the distribution of wetlands.

In which area of the map are there fewest wetlands? _____

Why are there few wetlands here? (You will have to think back to the maps you made in Exercise 1).

Leave WETLANDS map open.

Now you will direct the computer to find all the urban, that is all the areas in codes 1 through 8. Therefore you will recode all the landuse codes other than urban (9 to 30) to zero (transparent) and the urban codes (1 to 8) to 3. Why 3 was chosen will become apparent later.

Go to Analysis -> Database Query -> RECLASS

Type of file to reclass: image.

Classification type: used defined reclass.

Input file: double click on empty box

Click on LANDUSE on list

Click OK.

Output file: type URBAN

Assign a new value of: type 0

To all values from: type 9

To just less than: type 31

Click on right hand arrow to enter next code - check it reads 2 beneath the arrows. If it read anything more, use the left arrow to get back to 2. **YOU MUST NOT HAVE ANY BLANK CLASSES.**

Assign a new value of: type 3

To all values from: type 1

To just less than: type 9

Click OK.

To display URBAN:

Go to Display -> Display Launcher.

Enter the following:

Type of file: image file (raster).

Name of file to display: double click on empty box

Click on URBAN on list

Click OK.

Map Components: click on legend (x appears in box).

Palette options: click on QUALITATIVE 16.

Click OK.

Look carefully at the distribution of urban areas.

Leave URBAN map open and place it next to the WETLANDS map so you can see both together, by clicking and dragging on top blue bar of map.

Notice the codes for each.

You will now direct the computer to answer the question: “Which urban areas are within 500 feet of wetlands?”

To create the 500 foot buffer zones (or circles) around each wetland, this GIS will first construct a distance surface from every wetland to the edge of the map. You will then use RECLASS to define 500 foot buffer zones.

Go to -> Analysis -> Distance Operators -> DISTANCE

Enter the following:

Feature image: double click on empty box

Click on WETLANDS

Click OK.

Output image: type DISTANCE

Click OK.

This may take a while. You can monitor its progress in the lower right hand box, it will make 4 passes. When box is empty the analysis is complete.

To display DISTANCE:

Go to Display -> Display Launcher.

Enter the following:

Type of file: image file (raster).

Name of file to display: double click on empty box

Click on DISTANCE on list

Click OK.

Map Components: click on legend (x appears in box).

Palette options: click on QUALITATIVE 256.

Click OK.

To see exactly what has been done, zoom in using the Zoom-in Tool (9th from left - magnifying glass) on tool bar.

Click on center of map - it will enlarge. Reselect the Tool before each click.

Use the scroll bar to move the map around so that you can inspect other areas.

Notice the wetlands are black and each distance zone is a pixel wide.

Use the Zoom-out Tool (8th from left - rectangle within rectangle) to return map to original size. Place cursor on center of map and click on RIGHT mouse button. It should return to original size at once.

If necessary reposition map by double clicking on the map, red dots appear at edges.

Place the cursor on the dot on the top edge, it becomes a double arrow, then click and drag.

Now you have to define the buffer zones. You will reclassifying the wetlands (0) as 1, the 500 foot buffer (1 to 500) as 2, and the rest of the map (501 to 10000) as 0 (transparent).

Go to Analysis -> Database Query -> RECLASS

Type of file to reclass: image.

Classification type: used defined reclass.

Input file: double click on empty box

Click on DISTANCE on list

Click OK.

Output file: type BUFFER

Assign a new value of: type 1

To all values from: type 0

To just less than: type 1

Click on right hand arrow to enter next code - check it reads 2 beneath the arrows. If it read anything more, use the left arrow to get back to 2. YOU MUST NOT HAVE ANY BLANK CLASSES.

Assign a new value of: type 2

To all values from: type 1

To just less than: type 501

Click on right hand arrow to enter next code - check it reads 3 beneath the arrows. If it read anything more, use the left arrow to get back to 3. YOU MUST NOT HAVE ANY BLANK CLASSES.

Assign a new value of: type 0

To all values from: type 501

To just less than: type 10000

Click OK.

To display BUFFER

Go to Display -> Display Launcher.

Enter the following:

Type of file: image file (raster)

Name of file to display: double click on empty box

Click on BUFFER on list

Click OK.

Map Components: click on legend (x appears in box).

Palette options: click on QUALITATIVE 16.

Click OK.

Wetlands appear blue with a yellow circular buffer around each. Check codes.

To find the urban areas which are within the 500 foot buffer zones around the wetlands, you will use a procedure called CROSSTAB. This looks at each pixel, first on one map and records its value and then at the same pixel on the other map and records its value. The new map then shows all the possible combinations of values.

Go to Analysis - . Database Query -> CROSSTAB

Enter the following:

First image: BUFFER

Second image: URBAN

Output type: Cross-classification image

Output image: type ENDANGER

Click OK.

To display ENDANGER

Go to Display -> Display Launcher.

Enter the following:

Type of file: image file (raster).

Name of file to display: double click on empty box

Click on ENDANGER on list

Click OK.

Map Components: click on legend (x appears in box).

Palette options: click on QUALITATIVE 16.

Click OK.

Study the legend carefully. It tells you what combination each code represents.

Remember:

On the first map: BUFFER

code 0 was background

code 1 was wetlands

code 2 was buffer zones

On the second map: URBAN

code 0 was background

code 3 was urban

Using this, fill in the codes for ENDANGER:

code 1 is 0/0 - this is background/background

code 2 is 1/0 - this is _____

code 3 is 2/0 - this is _____

code 4 is 0/3 - this is _____

code 5 is 2/3 - this is _____

You can now create a final map to show the wetland areas, urban areas, urban within buffer zones, and background. This can be done by custom coloring the map to improve its appearance. As you do not need the buffer zones to show, they can be colored the same as the background.

Go to Display -> Palette Workshop

Click on the SECOND black square, the number 1 beneath turns red - it is now active. This is code 1, the background. Move the three sliders (red, green and blue) to the right, so that they all read 255. The square should now be white. That's the background color.

Click on the third black square, the number 2 beneath turns red - it is now active. This is code 2, the wetlands. Move the green and blue sliders to the right, this colors the square. Select a suitable blue shade for the wetlands.

Click on the fourth black square, the number 3 beneath turns red - it is now active. This is code 3, the buffer. Move the three sliders (red, green and blue) to the right, so that they all read 255. The square should now be white. That's the background color.

Click on the fifth black square, the number 4 beneath turns red - it is now active. This is code 4, the urban areas. Move the sliders to the right, this colors the square. Select a suitable shade e.g. yellow or green for the urban.

Click on the sixth black square, the number 5 beneath turns red - it is now active. This is code 5, the urban within buffer. Move the sliders to the right, this colors the square. Select a suitable bright contrasting shade e.g. red, for the urban within buffer.

Autoscale minimum: type 0

Autoscale maximum: type 5

To save these colors, **still in Palette workshop:**

Go to **File in Palette workshop** -> Save as:

Save file as: type ENDANGER

Click OK.

Close Palette workshop.

To recolor the map with new palette ;

Go to Composer (to the right of your map).

Click on *Properties*.

Enter the following:

Palette file: double click on box

Click on ENDANGER

Click OK.

Click OK.

All the urban areas that fall within a buffer are now highlighted in the bright color you selected.

Click on Zoom-in Tool ((9th from left) on tool bar.

Click on center of map - it will enlarge. Reselect Tool with each click.

Use the scroll bar to move the map around so that you can examine the map in more detail.

Use the Zoom-out Tool (8th from left) to return map to original size. Place cursor on center of map and click on RIGHT mouse button. It should return to original size at once. Reposition if necessary.

Add the ROADS and HIGHWAY to the map. These are vector layers.

Go to Composer:

Click on *Add Layer*.

Enter the following:

Vector file to display: double click on empty box

Click on ROADS to highlight

Click OK.

Symbol file (this is the colors): click on STANDARD DEFAULT

Click OK.

Click OK on original Add Layer box.

Repeat and add HIGHWAY using STANDARD DEFAULT for Symbol file.

Zoom in and scroll to examine the map in detail.

NOTICE all the urban areas within the buffer zones are highlighted, however the buffer zones are only 480 feet wide because of the limitation of cell resolution (pixel size, which is 160 feet).

Does this GIS give you an accurate picture of which wetlands are most under threat?
Explain your answer.

To close this exercise, double click on small box in top left corner of the MAP window for each map.

Now please could **each** student fill in a questionnaire on this GIS.

Group: _____ Student B:

IDRISI (GREEN)

What did you like about the way this GIS performed the overlays in Exercise 1?

What did you dislike about the way this GIS performed the overlays in Exercise 1?

What did you like about the way this GIS performed the analysis in Exercise 2?

What did you dislike about the way this GIS performed the analysis in Exercise 2?

How well did this GIS define (show) the endangered wetlands in Exercise 2?

FINISHED

Return these instructions to the front desk.

While you take a break discuss what you have just done. What did you like and dislike about this GIS? How effective was it at helping you solve the research questions?

Remember you will be asked to rank and comment on this GIS program at the end of the session.

STUDENT QUESTIONNAIRE

Once you have finished all the exercises using the paper and the electronic systems, please fill out this questionnaire as accurately as possible.

Age: _____

Male/Female

Grade: _____

1. How do you rate yourself: (check the boxes)

| | Expert | Advanced | Inter- mediate | Novice | No experience |
|-----------------------------|--------|----------|-------------------|--------|------------------|
| Using a PC | | | | | |
| Using a Macintosh | | | | | |
| Using new software | | | | | |
| Your geographical knowledge | | | | | |

2. Rank each of the GIS systems, **1 (best)** through **5 (worst)** for the following:

| | GIS 1 White Manual | GIS 2 Red Map Fact. | GIS 3 Blue ArcView | GIS 4 Green IDRISI | GIS 5 Yellow MapInfo |
|---|--------------------------|---------------------------|--------------------------|--------------------------|----------------------------|
| Performance on Ex 1 - overlays | | | | | |
| Performance on Ex 2 - analysis | | | | | |
| Ease of operation | | | | | |
| Most intuitive to use | | | | | |
| Quality of screen graphics | | | | | |
| Quality of hardcopy | | | | | |
| Helped your understanding of the geographic concepts | | | | | |
| Most fun to use | | | | | |
| Like to use again | | | | | |

3. Would you like this software available in your high school classes?

4. Give at least two reasons why you think you would find it useful in school.

5. Other Comments: (about GIS programs in general and/or about specific programs).
Use the back of this sheet.

Appendix H
High School Technological Evaluation

Technology Questionnaire:

COMPUTER AVAILABILITY AND CAPABILITY

| Lab # | # of Student Computers | PC/MAC | Type of PC or MAC | Memory (RAM) | Hard Disk Capacity | Networked Yes/No | Network Type (Ethernet) | Server Memory (RAM) | Server Disk Capacity |
|-------|------------------------|--------|-------------------|--------------|--------------------|------------------|-------------------------|---------------------|----------------------|
| 1 | | PC/MAC | | | | Y/N | | | |
| 2 | | PC/MAC | | | | Y/N | | | |
| 3 | | PC/MAC | | | | Y/N | | | |
| 4 | | PC/MAC | | | | Y/N | | | |
| 5 | | PC/MAC | | | | Y/N | | | |

2. Do social studies classes have access to a computer lab? Y/N

3. Would any particular lab not be available to them? Y/N If yes, which one(s)? Lab _____

Please include your name and telephone number, so I may contact you if any clarification is necessary.

Name: _____

School: _____

Telephone: _____

Table 37

The Technological Status of High Schools in the Study Area

| School | # Computers | Type | Operating System | Memory MB of RAM | Hard Disk Capacity MB | Networked Yes/No | Server Memory MB of RAM | Server Disk Capacity MB | Accessible to SS Classes |
|----------------|-------------|---------------|------------------|------------------|-----------------------|------------------|-------------------------|-------------------------|--------------------------|
| Allegan | NP | PC386/486 | DOS 5/6 | NP | NP | Yes | NP | NP | Yes |
| Otsego | 55 | PC | DOS | 4 | None | Yes | 12 | 1000 | No |
| Delton Kellogg | 70 | PC386/486 | Win | 4-8 | 150-250 | Yes | NP | NP | Yes |
| | 40 | MacPlus/LC II | old/7.1 | min/4 | None/80 | Yes | NP | NP | Yes |
| Athens | 20 | PC286 | DOS | 0.64 | 20 | No | NA | NA | No |
| Harper Creek | 25 | Mac | 7.1 | 4 | 80 | Yes | 16 | 120 | Yes |
| Lakeview | 28 | Apple IIe | NP | NP | None | No | NA | NA | Yes |
| Marshall | 22 | PC286 | DOS 6.2 | 0.64 | 21 | No | NA | NA | No |
| Three Rivers | 12 | Mac Plus | NP | 1 | NP | No | NA | NA | No |
| Climax-Scotts | 50 | PC | DOS 3.3/6.2 | 1/8 | 40/250 | Yes | 16/32 | 400/800 | Yes |
| Comstock | 48 | PC286 | DOS 3.1 | 1 | None | Yes | NP | 100 | No |
| Kal.Loy Norrix | 72 | PC286/386/486 | DOS 3.3 | NP | NP | Yes | 16 | NP | No |

| School | # Computers | Type | Operating System | Memory MB of RAM | Hard Disk Capacity MB | Networked Yes/No | Server Memory MB of RAM | Server Disk Capacity MB | Accessible to SS Classes |
|-----------------------------------|-------------|------------------------|------------------------------------|------------------|-----------------------|-------------------|-------------------------|-------------------------|--------------------------|
| | 16 | Mac | | 8 | 80 | No | NA | NA | Yes |
| Portage Central | 55 | MACLCIII/ LC550-475 | 7+ | 4/8 | 160 | Yes | 8 | 250 | Yes |
| | 60 | PowerMac | 7+ | 8 | 500 | Yes | 16 | 700 | Yes |
| | 30 | 30/286 | DOS | 2 | none | Yes | 8 | 350 | Yes |
| Schoolcraft | 22 | PC | DOS | NP | NP | Yes | 40 | 80 | No |
| KAMSC | 50 | MAC | 7.1 | 5 | 80 | Yes | 16 | 1000 | No |
| | 10 | PC486 | Win3.1 | 4 | 120 | Yes | 16 | 1000 | No |
| Hackett | 35 | PC285/385 | DOS/Win | 2/4-8 | 120/80-280 | No | NA | NA | No |
| Kal. Christian | 36 | PC | DOS 6.22 | 4 | 240 | No | NA | NA | No |
| Decatur | 20 | PC386 | Win | 2 | 45 | No | NA | NA | No |
| Gobles | 29 | PC | NP | 0.64/8 | None | Yes | 16 | 400 | No |
| Mattawan | 28 | PC486 | NP | 8 | 400 | Yes | 8 | 850 | Yes |
| SS Classes—Social Studies Classes | | | NP—Not Provided by the respondent. | | | NA—Not Available. | | | |

Table 38

Information on Schools Responding to the Questionnaire

ALLEGAN INTERMEDIATE SCHOOL DISTRICT

| School | Student Enrollment 1994-95 | Environment | #Students per computer |
|---------|-------------------------------|-------------|---------------------------|
| Allegan | 767 | Rural | NP |
| Otsego | 686 | Rural | 12:1 |

BARRY INTERMEDIATE SCHOOL DISTRICT

| School | Student Enrollment 1994-95 | Environment | #Students per computer |
|----------------|-------------------------------|-------------|---------------------------|
| Delton Kellogg | 567 | Rural | 5:1 |

CALHOUN INTERMEDIATE SCHOOL DISTRICT

| High Schools | Student Enrollment 1994-95 | Environment | #Students per computer |
|--------------|-------------------------------|-------------|---------------------------|
| Athens | 216 | Rural | 11:1 |
| Harper Creek | 816 | Rural | 33:1 |
| Lakeview | 1006 | Urban | 36:1 |
| Marshall | 798 | Urban | 36:1 |

CASS INTERMEDIATE SCHOOL DISTRICT

| School | Student Enrollment 1994-95 | Environment | #Students per computer |
|--------------|-------------------------------|-------------|---------------------------|
| Three Rivers | 800 approx. | Rural | 67:1 |

KALAMAZOO VALLEY INTERMEDIATE SCHOOL DISTRICT

| School | Student Enrollment 1994-95 | Environment | #Students per computer |
|------------------|-------------------------------|---------------|---------------------------|
| Climax Scotts | 197 | Rural | 4:1 |
| Comstock | 645 | Urban | 13:1 |
| Kal. Loy Norrix | 1292 | Urban | 15:1 |
| Portage Central | 1133 | Urban | 8:1 |
| Schoolcraft | 289 | Rural | 13:1 |
| KAMSC | 150 | Undesignated | 2:1 |
| Hackett Catholic | 486 | Undesignated | 14:1 |
| Kal. Christian | 482 | Undesignated- | 13:1 |

VAN BUREN INTERMEDIATE SCHOOL DISTRICT

| School | Student Enrollment 1994-95 | Environment | #Students per computer |
|----------|-------------------------------|-------------|---------------------------|
| Decatur | 267 | Rural | 13:1 |
| Gobles | 263 | Rural | 9:1 |
| Mattawan | 747 | Rural | 27:1 |

NP - Not Provided

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