USING COGNITIVE MEASURES TO PREDICT THE ACHIEVEMENT OF STUDENTS ENROLLED IN AN INTRODUCTORY COURSE OF GEOGRAPHIC INFORMATION SYSTEMS

A Dissertation

by

PAUL C. VINCENT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2004

Major Subject: Geography

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Approved as to style and content by:

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ABSTRACT

Using Cognitive Measures to Predict the Achievement of Students Enrolled in an Introductory Course of Geographic Information Systems. (December 2004)

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The cognitive factors of spatial ability, human-computer interaction, problem solving ability, and geographic attitude have been recognized as relevant to teaching and learning GIS. The goal of this research was to examine these cognitive abilities in university students taking an introductory course in GIS; examine any changes in these abilities after completing the class; and examine the relationship between those abilities and the students' grades in the class. It was hypothesized that students with higher cognitive ability scores would have higher grades than students with lower cognitive ability scores. Nine different self-report surveys were used to assess the students' spatial, computer, problem solving, and geographic cognitive abilities. The surveys were administered at the beginning and end of the two academic semesters. Analysis of the students' scores revealed a significant improvement on four of the nine cognitive ability surveys; one that measured computer experience and three that measured spatial ability. Bivariate correlations and multiple regression analyses were used to measure the relationship between the students' scores on the cognitive ability surveys and the students' grades. Students received grades on lecture exams, lab exercises, individual projects, and an overall grade. Only two of the bivariate correlations were statistically significant: the factors of geography attitude and learning style were significantly correlated with the students' project grade. Multiple regression analysis also revealed a very weak relationship, explaining less than 20 percent of the variance between the scores on the cognitive ability surveys and the students' lecture grade, lab grade, and overall grade. However, a much stronger relationship, explaining more than 45% of the variance, existed between the cognitive ability surveys and the students' project grade. These findings suggest that cognitive processes utilized for traditional classroom learning to pass lecture exams are different than those utilized to learn the software skills necessary to complete a GIS project. Therefore, it was concluded that the cognitive ability scores are poor predictors of grades related to traditional classroom learning such as lecture exams; however, these scores are more useful as predictors of the grades on a GIS project.

DEDICATION

I dedicate this to my family:

To those who were there from the beginning,

To those who joined along the way, and

To the memory of the one whose journey ended before this one did.

ACKNOWLEDGEMENTS

I am grateful to my committee for their service. I consider myself very fortunate to have worked with people held in such high regard in the community of geographers. I wish to acknowledge their service on my dissertation committee and their guidance in shaping me as a professional geographer.

I also wish to acknowledge the patience my family has granted me over the last seven years. You have all been so tolerant of my late night and early morning disappearing acts; you have been willing be apart countless weekends and holidays so I could work. Stacey, words cannot express my gratitude for the sacrifices you made to help make my far-fetched ambition become a reality. You have been patient, your have been kind, you have been loving, and you put the long in long-suffering. Now let’s do the things that we have always wanted to do but have neglected because I was always trying to finish something else on my dissertation.

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CHAPTER I

INTRODUCTION

Context of the Research Problem

Geographic information systems (GIS) has emerged as a rapidly growing sub-field within the discipline of geography. The sophistication of GIS technology and the number of users has increased so dramatically over the past two decades that it has been characterized as "phenomenal [because] no other word seems quite as appropriate" (Longley, et al. 1999). It has been speculated that the phenomenal growth of this technology has shifted the intellectual structure of the discipline of geography from regionally-oriented specialties to those requiring technical expertise (Gober, et al. 1995). Beyond this impact on the discipline of geography, GIS has developed into a major area of research and application, is widely recognized as part of the information technology mainstream, and has grown into a global industry worth more than $12 billion (Longley et al. 1999).

In appraising the discipline of geography, the National Research Council (1997) suggests the manner in which geography should respond to the GIS explosion. The authors of this report provide this directive: "Geographers will be responsible for preparing future generations of GIS users and must provide them with strong backgrounds in understanding geographic processes and patterns, spatial analysis, and

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This dissertation follows the style of the *Journal of Geography*.

spatial visualization techniques" (NRC 1997, 62). The NRC acknowledges that for geographers entering the job market, there has been an increase in the demand for technical expertise. However, they warn that without an adequate education, "those employing … geographic information systems in the public and private sectors will use that technology in inappropriate or inefficient ways" (NRC 1997, 140).

As GIS has grown as a technology, the need for adequate education in the use of GIS has also grown. With the growth of GIS as an industry during the late 1970s and early 1980s, planning and management agencies at all levels of government and business began to recognize the utility of GIS technology (Kemp and Goodchild 1991). During the mid-1980s, thousands of agencies began to rapidly implement GIS technology. This in turn led to a critical shortage of GIS operators, analysts, and managers and became an impediment to the adoption of GIS technology (Kemp, Goodchild, and Dodson 1992). To overcome this shortage, universities began including GIS in their curricula. However, universities found it difficult to implement these courses because of fiscal and planning barriers as well as a shortage of capable instructors (Kemp and Goodchild 1991; Wikle 1998). The 1990 release of the National Center for Geographic Information and Analysis' *Core Curriculum in GIS*, increases in the availability of cheaper computers, and instructional discounts for commercial GIS software stimulated the rapid growth of GIS as a university subject during the 1990s (Wikle 1998).

Cognitive Abilities Utilized in Learning GIS

As GIS has matured as a university subject and as the sophistication of the technology has increased, there has been an increase in awareness of the cognitive factors involved in the teaching, learning, and implementation of GIS (Medyckyj-Scott and Blades 1992; Nyerges et al. 1995; Albert and Gollege 1999; and Mark et al. 1999). Because GIS involves more complicated operations and decision-making processes relative to other information systems, several cognitive factors have been identified as important to the domain of GIS (Nyerges 1993; Wikle 1998; Mark et al. 1999). A review of literature related to GIS theory, application, and instruction reveals four dominant factors of human cognition that are particularly relevant to GIS. However, the studies described in the vast majority of this literature are conceptual and theoretical with few attempts to examine the importance of these factors in an experimental setting (Albert and Gollege 1999). The following is a brief description of these skills.

Spatial Ability

It has been widely recognized that spatial cognitive abilities are important in the use of GIS (Mark et al. 1999). Spatial ability is generally described as a set of skills that enable an individual to remember, manipulate, or recognize spatial stimuli (Montello et al. 1999). GIS users need spatial skills that provide the ability to mentally store and manipulate spatial objects for

> … fundamental tasks such as remembering what a specific map looks like, determining if a spatial pattern exists among different spatial objects on a map, determining the appropriate sequence of GIS operations or commands to produce a desired outcome, or

> trying to visualize a 3-D topography from an alternative perspective (Albert and Golledge 1999, 8).

Human-Computer Interaction

A second cognitive factor important to using GIS is the ability to interact with computers. Part of the process of learning to use GIS is learning how to operate new software and hardware. Since GIS requires that users acquire, store, manipulate, analyze, and generate a final product, all within a digital domain, an understanding of the functioning of a computer is vital. Because of the cognitive demands placed on the learner, GIS software is perceived as a complex tool to be mastered and a source of anxiety for beginners (Freundschuh and Gould 1991, Turk 1993).

Problem Solving Ability

A third cognitive factor is the ability to solve problems. This is a necessary skill because GIS is typically utilized to develop the solution to a spatial problem or set of spatial problems (Nyerges 1993). Successful use of GIS entails integration of spatially referenced data in a problem-solving environment (Cowen 1988). While the GIS provides a means for solving a spatial problem, users must have the ability to envision what spatial elements and analytical tools of GIS are necessary to generate a decision or an optimal solution to the problem through logic and reasoning skills (Nyerges 1993).

Geographic Ability

The fourth cognitive factor is geographic ability. As the name suggests, geographic information systems are linked with an understanding of geography. Because geography is about the study of space and spatial relationships, an understanding of geographic principles is necessary if users are to effectively implement the technology. Walsh (1992, 55) states:

> to know GIS one must first know geography … geographic knowledge regarding bio-physical and socioeconomic systems and the landscapes they produce relate to the ability of GIS analysts to interpret findings and make effective use of the analytic power of GIS.

In summary, this set of cognitive skills and abilities has been identified by GIS researchers and educators as playing a fundamental role in the effective use of GIS. Even though there is an abundant literature about teaching, learning, and applying GIS few attempts have been made to systematically research the precise role these factors play in the way people use and learn to use GIS. The studies that discuss these cognitive factors are conceptual, theoretical, or anecdotal. They fail to use appropriate methodology to experimentally demonstrate that these four factors are more important than other cognitive factors.

Purpose of the Study

The goal of this research is two-fold: 1) investigate the pre-existing cognitive skills and abilities of students enrolled in an introductory university course of GIS and 2) examine the relationship these cognitive factors have on the students' success in the class. By examining these aspects of human cognition, a conceptual model may be developed relating the individual cognitive differences of GIS students with their success in an introductory GIS course. Application of this model may aid in the development of more effective instructional strategies, contribute to the development of GIS curricula, such as the University Consortium for Geographic Information Science (UCGIS) curriculum project (see Marble 1999) and GIS certificate programs (see Wikle 1998), and suggest improvements in the user interface of GIS software.

There are two key questions addressed in this research. 1) Does taking a course in introductory GIS affect the students' cognitive skills/abilities and 2) Is there a predictive relationship between students' scores on tests of cognitive skills/abilities and their success in the GIS class? The relationship between these research objectives, the independent measures, the dependent measures, and the operational research questions are shown in Figure 1.

Surveys were used to measure the abilities or attitudes of students enrolled in an introductory university class of GIS in each of the four cognitive areas identified previously. The surveys of the cognitive factors were administered to the students at both the beginning and end of the semester. The scores on these surveys from the beginning of the semester were compared to the scores from the end of the semester to determine if the scores changed. Scores from the beginning of the semester were also correlated with the grades earned the by students in the lecture and the lab. Multiple regression was used to determine if a combination of cognitive factors or demographic variables is predictive of student success in a GIS class.

Research Objective	Independent Measures	Dependent Measures	Operational Questions
1. Does taking a GIS class improve the cognitive skill/abilities of students enrolled in a GIS class?	Computer Understanding and Experience Computer Attitude Geographic Attitude Measure Problem Solving Inventory Learning Style Inventory Card Rotation Test Hidden Figures Test Vandenberg Mental Rotations Test	None	1. What are the students' scores on the tests of cognitive skills at the beginning of the semester? 2. Are the students' scores on tests of cognitive skills statistically significantly greater at the end of the semester? 3. Are the scores of the different sub-populations statistically significantly different?
2. Is there a predictive relationship between students' scores on tests of cognitive skills/abilities and their success in the GIS class?	Same as above	Course grade Lecture grade Lab grade Project grade	1. How strong is the relationship between the factors measured by each test and the students' success in the class? 2. Can any of the factors act singly as a predictor of the students' success in the class? 3. Is there some combination of factors that can act as a predictor of students' success in the class?

Figure 1. *Relationship Between the Research Objectives, Independent Measures, Dependent Measures and Operational Questions.*

In addition, qualitative data were also collected to clarify and verify findings from the quantitative analysis. Data used in these analyses included observation of the lecture and practical computer activities, open-ended questionnaires, and interviews with the student participants.

Assumptions

1) This study assumes that the psychometric tests used to measure cognitive skills and attitudes are reliable and valid.
2) This study assumes that the participants will work independently and provide answers to the psychometric test questions that accurately represent their beliefs and knowledge.
3) The study assumes that the participants will provide answers to interview questions that accurately represent their beliefs and knowledge.
4) The students enrolled in the class are representative of the population of students enrolled in an introductory GIS class.
5) The instructor evaluated student performance accurately.

Limitations

1) Generalizations of the research findings are limited because the experimental treatment group is not randomly selected.
2) Because this research will not be part of the grading for the classes, students may have perceived it as irrelevant and that full cooperation was unnecessary.

3) Because this was not one of the professor's objectives for the class, he may have perceived it as unimportant and inadvertently limited the ability of the researcher to conduct this research.

CHAPTER II

REVIEW OF LITERATURE

Introduction

The research conducted for this dissertation examines the relationship of the four cognitive skills identified in the first chapter (spatial ability, human-computer interaction, problem solving ability, and geographic ability), and the success of novices learning to use GIS. The foundation of this research is drawn from relevant literature from the disciplines of Geography, Cognitive Science, Human-Computer Interaction, and Educational Technology. Because these are distinctly different disciplines, each offers a different aspect of how novices learn GIS. Research regarding the cognitive skills utilized when learning to use GIS is situated within the intersections of these four disciplines. Geography provides a disciplinary home for GIS, cognitive science provides insights into the way users learn GIS, human-computer interactions examine the ways humans interact with systems of computers, and Educational Technology provides an understanding of the way novices learn to use technologies such as computers and computer software in an educational setting.

Geography is often defined as the study of people, places, and environments and the “how” and “why” of the relationships that exist between those people, places, and environments. Although geography is defined as a discipline, it integrates the subject matter of many other disciplines in such a way that is often described as a multi-disciplinary or cross-disciplinary field of study.

GIS traces it origins to many disciplines that are unified by the study of spatial phenomena. Since geography is viewed as an integrating and synthesizing discipline, with a focus on spatial phenomena, it has been argued that Geography is the most suitable home for GIS (Morrison 1991; Kemp et. al. 1992). In this regard, Geography provides a conceptual and theoretical framework on which GIS curriculum can be built.

Although a cognitive component of GIS has been contemplated since the first international symposium on GIS held at Harvard University in 1977, it has not received the attention of researchers in educational technology and GIS applications. Of the cognitive skills, spatial cognition has received the greatest attention in the research literature. However, this strand of research consists primarily of theoretical and conceptual descriptions of the way in which humans perceive space in a GIS. Very little experimental research has been conducted with human subjects to support the claims found in this literature.

Research in human-computer interactions examines the bridge between the user and the hardware and software systems used in GIS. Human-computer interaction (HCI) seeks to optimize the relationship between people and the computer systems they use with particular emphasis on the user interface (Turk 1990). Turk (1990) concludes that there exists a great need for research in this area especially since much of the dissatisfaction expressed by users of GIS concerns the non-intuitive interface of the systems.

Research on the educational technology component of GIS has been related, in large part, to the development of models for the implementation of GIS in elementary and secondary schools in the United States. This includes such issues as linking the use of GIS with the five themes of geography (Nellis 1994), utilizing an inquiry or project-based approach into geographic instruction, or integrating GIS into the local or regional curricula (Bednarz and Ludwig 1997). However, this research is descriptive and anecdotal, rarely connecting teaching and learning practices that occur in GIS classes to relevant learning theory. With the exception of one recent study (Kerski 2000), there is little empirical measurement of changes in the learning outcome of the students where GIS is utilized.

This review is divided into two sections. The first section examines the growth of GIS as an academic subject as taught at colleges and universities in the United States. This includes tracing the history and development of GIS curricula and teaching strategies in GIS instruction. The second section focuses on the four cognitive factors that are relevant to novices who are learning to use GIS.

The History of GIS in American Academics

Origins of GIS

GIS can trace its roots to initiatives from many different fields of study. In many cases, advances and developments that occurred in these different fields took place without knowledge of what was occurring in the other fields (Coppock and Rhind 1991). While a wide variety of application areas contributed to the growth of GIS, the principle advances could not have occurred without a shift toward quantitative geography, greater environmental awareness and regulation, and the simultaneous advances in the technologies of computing, cartography, and photogrammetry (Star and Estes 1990). Although the beginnings of the modern era of GIS originated in the 1960s, its growth over the last four decades has been phenomenal. GIS has progressed from an esoteric field of computer science into a major area of research and application. It is now widely recognized as part of the information technology mainstream and has grown into a global industry worth more than $12 billion (Longley et al. 1999).

The pioneers of GIS were primarily involved in maintaining large, spatially referenced databases for government agencies engaged in land use management (Tomlinson 1984). This was the situation as GIS continued to expand during the 1970s to a variety of federal and state agencies as well as research universities (Foresman 1998). The GIS of those agencies was “a GIS” that was unique to the needs of that particular agency rather than a generic commercial software program like those available today. Research and development in GIS was more about technical issues of software development than commercial applications of today’s GIS (Chrisman 1998). Chrisman (1998) points out that, unlike today, the primary role of universities in the 1970s was discovering and promoting the feasibility of computer-handled geographic data systems. University research was limited because of the high cost of starting and maintaining a GIS facility (Tomlinson 1984). The early stages of research and development in GIS culminated in 1977 at a conference organized by the Harvard Laboratory for Computer Graphics and Spatial Analysis and sponsored by the US Geological Survey (USGS) and the US Census Bureau.

In the United States, the Harvard Lab, the USGS, and the Census Bureau were three of the most significant entities involved in the theoretical development of GIS, particularly with regard to topology and data structures (Coppock and Rhind 1991). Although each of these entities developed their own proprietary GIS software, only the Harvard Lab attempted, albeit unsuccessfully, to develop a commercial GIS product. However, the Harvard Lab served as a starting point for two individuals who went on to develop successful commercial systems: Dangermond of ESRI and Stinton of Integraph (Coppock and Rhind 1991). This began the transition from GIS being developed primarily in the public sector to a commercial product marketed to clients in both the private and public sectors (Foresman 1998).

During the 1980s, two significant advances promoted the rapid growth of GIS. The first was a shift in GIS software production. GIS evolved from unique systems, specially tailored for each agency, to a standardized, off-the-shelf, commercial product (Dangermond and Lowell 1988). The second advance that occurred was the introduction of more powerful personal computers. Advances in the microcomputer quickly led to a migration of GIS from mainframe computing to desktop computing (Clarke 2001). Rapid changes during the commercial development of GIS is summarized by Clarke (2001, 12) who states:

> Many older packages that failed to move to the new languages and platforms died out, to be replaced by newer systems that could exploit the capabilities of the more powerful equipment. Costs of storage fell remarkably, computer power increased many-fold, and the first generation of [graphical user interfaces, or] GUIs made the software considerably easier to use, adding features such as menus, on-line manuals, and context-sensitive help.

By the end of the 1980s, many of the technical difficulties that plagued GIS development and implementation in the 1970s had been overcome. Researchers and developers no longer worked in isolation and a well-developed means of information sharing among GIS professionals had been established (Coppock and Rhind 1991). A number of annual conferences, new academic journals, and trade publications provided a framework for the dissemination of knowledge regarding new techniques and areas of application in GIS (Clarke 2001).

However, the agencies using GIS now faced a new difficulty. As GIS began to move from a few large-scale GIS operations in government departments into small- and medium-sized agencies, the demand for personnel trained to use GIS exploded (Kemp and Goodchild 1991). Unfortunately, the supply of trained professionals could not keep up with the high level of demand, leading to a critical shortage of GIS operators, analysts, and managers (Kemp, et al. 1992). In order for the GIS industry to continue its rapid implementation, it would be necessary to establish a means to efficiently deliver GIS instruction.

Until the mid-1980s most of the GIS training was provided on the job by the agency who had developed the GIS or the vendor who provided the commercial GIS software (Tomlinson 1988). Tomlinson (1988) points out that early academic interest in GIS was more about intellectual pursuit than the development and management of large digital geographic databases. Chrisman (1998, 41) characterizes the involvement of the academic sector as providing "an environment of exploration and innovation." These notions had shifted by the mid-1980s when academics began to realize that they could teach GIS as well as conduct GIS research (Unwin 1991a). Morrison (1991, 99) declared that "universities must provide the training for [the shortage of] professional users."

Challenges Facing Academic GIS Instruction

While it was becoming apparent that GIS instruction was needed, several problems began to arise which stalled the growth of GIS as a university subject. The first problem was a debate with regard to which discipline should be the academic home of GIS or as Thompson (1987, 265) states: "GIS has not been put in its place." Because GIS can be applied in so many disciplines, GIS education had to meet the needs of a wide range of users (Rhind 1987). Morrison (1991) argued that the traditional view of geography as an integrating discipline with the focus on spatial phenomena should be the academic home for GIS. Kemp, et al. (1992) extended this idea to include three additional reasons for teaching GIS in geography: 1) GIS training provides marketable skills for geography graduates, 2) GIS is a tool to support scientific inquiry in geographic phenomena, and 3) geographic information is an intellectual theme within geography. Establishment of the National Center for Geographic Information and Analysis (NCGIA) in 1988 and its close association with geography departments helped promote GIS education in geography (Morrison 1991). In the results of a survey conducted in the 1991-1992 academic year, Morgan and Fleury (1993) concluded that geography departments had taken the lead in teaching courses of GIS.

Implementation became the second problem facing academic departments wishing to provide GIS instruction. The most significant of the implementation issues were the high cost of the necessary hardware and software and the lack of adequately trained personnel to teach a course in GIS (Wise and Burnhill 1991). It was concluded that the high cost of hardware and software was a perceptual problem. Commercially developed, proprietary GIS packages and the necessary hardware to maximize the software's capabilities were indeed expensive. However, the principles of GIS could be taught using software available in the public domain or in a disaggregate fashion using cheaper independent components such as spreadsheets for data manipulation and a drawing program for map production (Campbell 1991). However, the issue of cost was soon completely resolved when the price of desktop computers dropped dramatically in the early 1990s and commercial software vendors allowed universities to purchase their software at steep academic discounts (Wikle 1998).

The lack of trained instructors was a more difficult issue to overcome. First of all, the shortage was fueled by the supply/demand cycle for GIS professionals. GIS instructors often found in consulting and would leave their teaching position for a job in the private sector. Because of the demand for GIS instruction, a replacement without extensive GIS experience would be trained to teach the GIS class. As the new instructor would develop the GIS skills employees needed the replacement instructor would subsequently leave their academic job for a consulting position (Nyerges and Chrisman 1989). The immediate consequence of this cyclic process was not only a shortage of academics capable of teaching GIS but a teaching force many of whom had not even taken a course in GIS much less done research in GIS (Kemp and Goodchild 1991).

In addition to ill-prepared instructors, effective instruction was also limited by a lack of curricular materials such as textbooks, that for other subjects, were readily available. The lack of curricular materials created other dilemmas for academic GIS instructors. The most significant of these was knowing what content to teach and how it should be taught (Unwin 1991b). The instructor had to deal with the conflict between a need to teach in sufficient depth about the underlying concepts of GIS while covering applications with sufficient breadth so the students could appreciate the diversity of uses for GIS (Goodchild 1985). This concern was further complicated because it was unknown whether students taking GIS courses were gaining the skills employees needed (Morgan 1987). Morgan (1987) also discovered little consensus with regard to the prerequisites for taking a GIS class and the content that should be taught in those classes. Academics attempted to clarify these questions over the next several years through the development of an appropriate curriculum.

Academic Solutions

The development of a model GIS curriculum proved to be a difficult task. It was recognized very early that curricular needs could vary greatly depending on the kind and the level of expertise required of the students. Users, developers, and managers each might require a different set of courses and even different learning environments in order to develop the appropriate job skills (Nyerges and Chrisman 1989, King 1991). Thus, discussion (in peer reviewed journals) of a GIS curriculum was not only about a scope and sequence of topics relevant to academic GIS but the ways such a curriculum could be used to meet the needs of the different users of GIS. These discussions centered around issues such as GIS *education* versus technical *training*, the notion of teaching *about* GIS versus teaching *with* GIS, teaching about the *technology* in general or *applications* in particular, and concerns about teaching in a *lecture* format versus a *lab* format.

The late 1980s and early 1990s saw several attempts to produce a realistic and functional design for a course, or series of courses, to integrate GIS into a university's academic curriculum. A number of discussions had already taken place with regard to the curricular concerns for "automated cartography" and had laid a foundation on which to build the subsequent discussions about GIS curriculum (Nyerges and Chrisman 1989).

The first organized discussion with regard to GIS curricular concerns occurred at a special session on GIS education at the annual meeting of the Canadian Association of Geographers in 1985 (Kemp et al. 1992). The papers presented in that session were published later that year in a special issue of *The Operational Geographer* (see Douglas 1985; Goodchild 1985; Maher and Wightman 1985; Muller 1985; and Poiker 1985). Much of the discussion in these papers centered around the concerns of teaching GIS in an undergraduate university setting, how it was perceived that GIS would change geography departments, and how GIS would ultimately influence the discipline of Geography. Although these papers identified the instructional issues, there was very little discussion with regard to the manner in which they should, or even could, be resolved.

Following this initial discussion in 1985, most major GIS conferences held sessions on GIS and education and a series of conferences were held at Ohio State University concerned with the issues of teaching GIS (Unwin 1991b). Published accounts of the justification for teaching GIS in a particular fashion and the methods utilized to overcome the obstacles of implementing a GIS curriculum were soon appearing in the relevant journals (see Nyerges and Chrisman 1989; Unwin et al. 1990; Keller 1991; King 1991; Kemp and Goodchild 1991; Raper and Green 1992; Dramowicz et al. 1993). This proliferation of ideas for GIS curricula was characterized by King (1991, 66) as “GIS fever” and by Sui (1995, 578) as a “megatrend in geographic education.” However, except for two projects, most of these reports represented isolated and uncoordinated attempts by individuals or individual departments to implement GIS instruction. Barring those same two exceptions, there was very little response to these efforts and no documentation in the literature to suggest that these efforts were successful elsewhere or even continued to be successful in the institution where they were developed.

The AutoCarto syllabus (Unwin et al. 1990) and the NCGIA Core Curriculum Project (Kemp and Goodchild 1991) are the two notable exceptions. Both of these curricula were developed as collaborative projects and responses to their content were published. The AutoCarto syllabus is a more modest effort while the NCGIA Core

Curriculum Project (CCP) was developed to have a large, immediate impact on the direction of GIS in higher education.

The AutoCarto syllabus was the result of a two-day symposium held at the University of Leicester in 1988 (Unwin et. al. 1990). There were nine participants with a wide range of interest in GIS. The final product of the symposium was a syllabus of 37 lectures found within six sections. An outline of the syllabus is given in Figure 2. The authors of the syllabus admit their effort is not complete. They state that their syllabus

> … is essentially content driven, determined by what one group meeting in the late 1980s happens to think should be assimilated as 'knowledge' by our students. By and large, it neglects important curriculum issues of how this content should be delivered to enhance educational experience and employability and what values it might inculcate.
>
> Any complete curriculum for teaching GIS should address deeper questions about its educational aims and objectives, teaching methods and, since they often determine the so-called 'hidden curriculum', how it is assessed and evaluated. … Viewed from this perspective, specification of a sample course syllabus can only be a preliminary first step towards providing such a complete curriculum (Unwin et al. 1990, 463).

Response to the AutoCarto syllabus was small, and after the initial response, it has faded away. Most of what was published came from one of the authors of the syllabus (see Unwin and Dale 1990 Unwin 1991a; Kemp and Goodchild 1991). Besides the problems already mentioned, others criticized it for being merely a list of suggested materials that could be included in a GIS program (Unwin 1991a).

The NCGIA CCP was similar in some respects to the AutoCarto efforts but much more ambitious. Beginning in 1988, the National Center for Geographic Information and Analysis (NCGIA) received five years of federal funding to

Section 1:	**Introduction—the context for GIS.** Three lectures on definitions and history, data and information as a commodity, and an 'advance organizer' real world example to illustrate GIS potential.
Section 2:	**Cartographic and spatial analytical concepts in GIS.** Eleven lectures on types of spatial data, georeferencing, map projections, coordinate transformations, fundamental spatial concepts, and basic operations on points, lines, areas, and surfaces
Section 3:	**Realization in a computing environment** Eight lectures on digital representation of information at low and high levels, data models (raster, vector, object oriented), errors, the vector/raster debate, and relevant advances in computing
Section 4:	**Operational considerations** Five lectures on hardware, data storage media, processors and processing environments, displays and an example study of at least one production system
Section 5:	**Applications of GIS** Five lectures on applications fields, global scale use, decision making using GIS, project management and cost-benefit analysis
Section 6:	**Institutional issues** Five lectures on access to data, quality assurance and standards, legal implications, GIS and management and education and training

Figure 2. *Basic Units Within the AutoCarto GIS Syllabus (from Unwin 1990).*

> … conduct research and educational initiatives directed at decreasing or removing impediments to the adoption of GIS technology … The educational initiatives are designed to improve access to GIS education and to increase availability of skilled GIS personnel, researchers and faculty (Kemp and Goodchild 1991, 123-4).

The organizers of the NCGIA argued that an easily adaptable set of teaching materials should be designed and distributed in order to have the most significant impact on the GIS courses taught in higher education (Kemp et al. 1992). The purpose of this teaching material was

> … to provide a general education on the basic principles and concepts of GIS, to examine the theory and tools of spatial information analysis and to provide a broad exposure to GIS applications so that objective decisions can be made about system acquisition, implementation and use (Kemp and Goodchild 1991, 125).

An initial outline for a one-year course sequence of 75 lecture topics was developed through a series of discussions with the GIS community. Ultimately, some 35 GIS educators in the United States, Canada, and the United Kingdom contributed material to the first draft. The first draft was evaluated and tested at over 100 sites during the 1989-90 academic year (Kemp 1991). Based on comments from evaluators of the first draft, a revised version was released for general distribution in July 1990. An outline of the final version of the core curriculum is presented in Figure 3.

Besides the magnitude of the NCGIA CCP, it differed from the AutoCarto syllabus in two significant ways. First, instead of merely providing an outline of lecture topics, the NCGIA also provided a set of lecture notes for each of the 75 topic areas. Second, the CCP also provided supplementary materials such as instructional data sets, overhead transparency masters, laboratory exercises, bibliographic entries, and even sample examination questions (Kemp and Goodchild 1991). Altogether, more than 1000 pages of material were included in the lecture notes and supplemental materials.

The NCGIA's Core Curriculum was received enthusiastically by the GIS community. By the end of 1995, over 1500 copies had been distributed throughout the world (Kemp 1997). Although educational institutions were the principle recipients of the Core Curriculum it was also widely distributed to commercial GIS vendors, private consultants, and government agencies (Goodchild and Kemp 1992). The 1990 print

I. Introduction to GIS

A. Introduction
- 1. What is GIS?
- 2. Maps and map analysis
- 3. Introduction to computers

B. A first view of GIS
- 4. Raster GIS
- 5. Raster GIS capabilities

C. Data acquisition
- 6. Sampling the world
- 7. Data input
- 8. Socio-economic data
- 9. Environmental data

D. Spatial databases
- 10. Models of reality
- 11. Spatial objects and database models
- 12. Relationships among spatial objects

E. Vector view of GIS
- 13. Vector GIS
- 14. Vector GIS capabilities

F. Using the GIS
- 15. Spatial analysis
- 16. Output
- 17. Graphic output design issues
- 18. Modes of user/GIS interaction
- 19. Generating complex products
- 20. GIS for archives

G. Past, present and future
- 21. Raster/vector debate
- 22. Object/layer debate
- 23. History of GIS
- 24. GIS marketplace
- 25. Trends in GIS

II. Technical issues in GIS

H. Coordinate systems and geocoding
- 26. Common coordinate systems
- 27. Map projections
- 28. Affine and curvilinear transformations
- 29. Discrete georeferencing

I. Vector data structures and algorithms
- 30. Storage of complex spatial objects
- 31. Storage of lines: chain code
- 32. Simple algorithm I—line intersections
- 33. Simple algorithm II—polygons
- 34. Polygon overlay operation

J. Raster data structures and algorithms
- 35. Raster storage
- 36. Hierarchical data structures
- 37. Quadtree algorithms and spatial indexes

K. Data structures and algorithms for surfaces, volumes and time
- 38. Digital elevation models
- 39. TIN data model
- 40. Spatial interpolation I
- 41. Spatial interpolation II
- 42. Temporal and 3D databases

L. Databases for GIS
- 43. Database concepts I
- 44. Database concepts II

M. Error modeling and data uncertainty
- 45. Accuracy of spatial databases
- 46. Managing error
- 47. Fractals
- 48. Line generalization

N. Visualization
- 49. Visualization of spatial data
- 50. Color theory

III. Application issues in GIS

O. GIS application areas
- 51. GIS application areas
- 52. Resource management applications
- 53. Urban planning and management
- 54. Cadastral records and LIS
- 55. Facilities management
- 56. Demographic and network applications

P. Decision-making in a GIS context
- 57. Multiple criteria methods
- 58. Location-allocation on networks
- 59. Spatial decision support systems

Q. System planning
- 60. System planning overview
- 61. Functional requirements analysis
- 62. System evaluation
- 63. Benchmarking
- 64. Pilot project
- 65. Costs and benefits

R. System implementation
- 66. Database creation
- 67. Implementation issues
- 68. Implementation strategies for large organizations

S. Other issues
- 69. GIS standards
- 70. Legal issues
- 71. Development of a national GIS policy
- 72. GIS and global science
- 73. GIS and spatial cognition
- 74. Knowledge based techniques
- 75. The future of GIS

Figure 3. *Outline of the NCGIA Core Curriculum (from Goodchild and Kemp 1992).*

version is no longer available except as an on-line document at http://www.geog.ubc.ca/courses/klink/gis.notes/ncgia/toc.html. Another version is currently under review by the NCGIA for on-line distribution only. It is described as a working document with continuous updates as the technology changes. However, the weakness of this model are that it is difficult to find funding for continuous maintenance, and the updates are written by volunteers who have no assurance of gaining academic credit for their work (Foote 1999). This problem is evident for the NCGIA CCP as the website has not been updated since August 2000 (http://www.ncgia.ucsb.edu/education/curricula/giscc/).

Despite the ambition of the project and enthusiasm of the response, the NCGIA's core curriculum received numerous criticisms. Initially, these complaints were minor in scope. The complaints were generally about the organization and structure of the Core Curriculum. One such complaint was that the Core Curriculum included too much overlap (Coulsen and Waters 1991). In their efforts to implement the Core Curriculum, Coulsen and Waters (1991) found the lecture notes were not only repetitive but also included considerable material typically covered in classes of cartographic principles and remote sensing as well as other prerequisite classes. Unwin and Dale (1990) concluded that because of the extent of the overlap, all three courses must be completed for students to obtain a comprehensive overview of issues relevant to GIS.

Another of the minor complaints was that the lecture outlines and laboratory exercises were too structured (Kemp 1991). This led to a cookbook approach and the concern that the "easily acquired support materials may well mean that in practice it is simply too prescriptive and too elementary for many purposes" (Unwin and Dale 1990, 307). Unwin (1991a, 86) was concerned that the materials "will be passed uncritically to students for many years to come."

However, the most significant complaint, as with the AutoCarto syllabus, was that the CCP was largely content driven (Unwin and Dale 1990). Unwin and Dale (1990, 310) explained that the curriculum is "teacher centered, catering for the needs of the type of student [referred] to as a 'knowledge seeker' as opposed to an 'understanding seeker.'" Jenkins (1991, 104) stated that "there is always an immense concern with what should be taught while the how of teaching is seldom carefully analyzed." Sui (1995, 578) complains that "the NCGIA GIS Core Curriculum is concerned with what should be taught, while displaying less concern for how it should be taught, to whom, and in what circumstances."

Aside from these complaints, the NCGIA did serve as an important catalyst in the growth of GIS in higher education. According to Coulson and Waters (1991, 101)

> … the core curriculum has begun the process of identifying and structuring standards of course content in GIS. It has caused us to reconsider not only what we are teaching, but what should have preceded the GIS course and when. It has also begun the discussion towards professional agreement on what constitutes a well-trained GIS practitioner.

How to Teach GIS

Although the "what" of teaching GIS may not have been conclusively solved through these curriculum efforts, the "how" of teaching GIS is even more uncertain. A variety of strategies for teaching GIS has been proposed since the beginning of the

1990s. These proposals apply to as little as a single GIS concept or as much as a complete class. These strategies describe either a means of teaching *about* GIS or teaching *with* GIS (Thompson 1987; Sui 1995). Thompson (1987) argues that teaching about GIS should concentrate on GIS technology with an instructional focus on training. On the other hand, teaching with GIS should focus on GIS applications with an instructional emphasis on geographic content education. GIS is either the object of the instruction—teaching *about* GIS—or the tool of instruction—teaching *with* GIS (Kerski 2000). Sui (1995) describes a model for using Berry's Geographic Matrix as a pedagogic tool to teach both *about* and *with* GIS.

Although there is consensus among GIS experts that there is a need for instruction regarding GIS software, GIS techniques, and geographic content, there is no consensus as to how it should be taught (Sui 1995; Chen 1998). As the development of the AutoCarto Syllabus and NCGIA CCP unfolded, literature proposing methods of how to teach GIS began to grow (see Campbell 1991; Blakemore 1992; Raper and Green 1992; Rogerson 1992; Walsh 1992; Keller et. al 1996; Foote 1997; Thompson et. al 1997; Chen 1998; Benhart 2000). Some of these strategies proposed using software less complex or less expensive then an off-the-shelf GIS, some suggested a problem-solving or project-oriented approach, and others suggested learning aids to help students grasp concepts more quickly. In each of these examples however, the research focused on the GIS program at an individual institution with little concern with how successfully GIS was being learned. While these efforts are interesting and noteworthy, they are descriptive accounts of the experiences that the students and instructors had in response to their experiences with these teaching strategies.

Most of the literature discussed so far has been concerned with teaching *about* GIS. Several authors have indicated that teaching *with* GIS is a useful way to teach geography. Because GIS promotes an inquiry-based approach to teaching, it is seen as a useful tool for promoting the national standards in geography (Geography Education Standards Project 1994). Research by Keiper (1999) found that although teaching geography with GIS in a fifth grade classroom can be frustrating, it also allows the students opportunities to practice their geographic skills. Kerski (2000) found that utilizing GIS in secondary classrooms strengthened some geographic skills of students in those classes.

Current Trends in GIS Education

Even though Kemp and Frank (1996, 477) go so far as to declare that "GIS education is finally maturing," it does not appear that academic GIS is meeting the needs of the professional community. The demand for GIS professionals continues to grow, and the complexity of knowledge necessary to enter the profession has also increased (Wikle 1998). Gober et al. (1995, 325) note that recent graduates with GIS training are becoming "button pushers who know cookbook applications but are unable to work through a problem from start to finish." The NRC (1997, 140) warns that if users of GIS do not receive adequate education, they will use the technology in "inappropriate or inefficient ways." Finally, Marble (1998) expresses concern that academic classes in

GIS are becoming too focused on software training and not teaching the critical concepts of GIS sufficiently.

In an effort to address the renewed concern for GIS education, two efforts are underway; however, both of these are works-in-progress and their impact remains to be seen. The first is the development of a multi-path curriculum by the University Consortium for Geographic Information Science (UCGIS). At the recommendation of the NCGIA's steering committee the UCGIS was established in 1995 to promote and support the field of GIS (Mark and Bossler 1999). While the UCGIS is not an educational organization, it has established an initiative to create a model curriculum for the fields of study that utilize GIS (Marble 1999). This curriculum is yet to be published, but commentary on the development of this curriculum, found on the UCGIS website (www.ucgis.org), suggests it will be content-driven much like the AutoCarto syllabus and the NCGIA Core Curriculum Project. This preliminary information suggests that the biggest difference between the efforts of the UCGIS and the two previous efforts is that the UCGIS will have greater breadth. This curriculum will "specify several paths corresponding to those required by students involved with [GIS] at various levels and will identify the course to be associated with each path" (Marble 1999, 31). Marble (1999) indicates that the paths will vary depending on the disciplinary focus (i.e., geography, urban planning, resource management, etc.) of the student and the level (i.e., GIS analyst, manager, software developer, etc.) at which the student ultimately wishes to work. At present, it is unclear if these "paths" will be suggestions for classes to be taken, a set of topics that should be covered, or something more complex.

A second effort to assure GIS competency is through the development of certification for GIS professionals. Presently, there are two ways that a certificate may be obtained, neither of which requires a formally recognized examination. The American Society for Photogrammetry and Remote Sensing (ASPRS) presently provides professionals the opportunity to become a Certified Mapping Scientist. However, this certification is obtained largely through gaining the appropriate number of years experience in using GIS on the job. Besides the ASPRS certificate, several universities offer a GIS certificate upon completing the required number or type of classes. Although holding either of these certificates would strongly suggest some level of qualification, the certificates do not guarantee that the person holding the certificate has any ability to use GIS.

A number of authors have discussed the issue of a professional GIS certification, licensing, or accreditation through examination (see Goodhild and Kemp 1992; Obermeyer 1993; Burley 1993; Wikle 1998; Wikle 1999). Although the effort to develop a GIS professional examination is gaining momentum and support from organizations such as UCGIS, ASPRS, and the Urban and Regional Information Systems Association (URISA), a number of obstacles remain to be overcome. Many of these obstacles are similar to those that were faced during the initial efforts to develop a GIS curriculum. The principal concerns include: 1) what organization should serve as the certifying agency since no organization for all GIS professionals exists; 2) should it be a single broad certification or should each field of GIS application have its own certification? These issues are still being debated in professional and academic GIS circles. It is unlikely that the final outcome of a certification process on GIS education will be known for quite some time.

Cognition and GIS

Introduction

As advances in computer technologies enabled improvements in GIS hardware and software systems, the awareness of the cognitive aspects of GIS has also grown. Nyerges (1993, 37) states:

> Since the scope of GIS data processing includes a combination of data capture and display, spatial analysis and database activities in the context of complex decision-making, GIS use tends to be more complicated than the use of traditional information systems. As a result, there is an enormous opportunity and challenge for research leading to a better understanding of GIS use.

Research in the cognitive factors utilized in the domain of GIS has generally focused on spatial cognition. The study of human-computer interaction (HCI) with regard to GIS has received some attention whereas geographic skill and problem solving ability have either been implied or assumed by researchers but not investigated directly. This section will examine relevant literature on the cognitive factors of spatial cognition, HCI, problem-solving ability, and geographic knowledge and the relationship of these factors in the use of GIS. All of these cognitive factors are important in learning to use GIS; however, none of them can be considered more important than another. Rather, these are domains that interact within users as they learn how to use GIS and answer spatial questions with GIS.

Spatial Cognition

It has been widely recognized that spatial cognitive abilities are important in the use of GIS (Mark 1993; Nyerges 1993; Turk 1993; Nyerges et. al. 1995; Freundschuh and Egenhofer 1997; Albert and Gollege 1999; Mark et. al. 1999). Mark et. al. (1999) suggest that research themes from the psychological origins of spatial cognition, cognition of geographic space, behavioral geography, cognitive research in cartography, and research about wayfinding and navigation converged during the mid-1980s to provide the theoretical backdrop for cognitive research in GIS. However, most of the research on GIS and spatial cognition has emphasized how geographic information is represented by a GIS and the way users interact with this information in the GIS as well as the real world (Albert and Golledge 1999). Much of the work so far is theoretical or conceptual with very little human-subject testing to support the concepts and theories that have been proposed.

In general, spatial ability is described as a set of skills that enable an individual to remember, manipulate, or recognize spatial stimuli (McGee 1979). Psychologists have investigated spatial abilities since the end of the 19th century and have developed more than 100 paper-and-pencil tests to measure spatial ability (see Eliot and Smith 1983 for example). These different tests represent the many ways that spatial ability has been conceptualized and operationalized. These tests require individuals to perform such tasks as "… find hidden shapes, match 2-D or 3-D figures, balance figures with respect to horizontal or vertical axes, solve mazes, imaging the results of rotations or manipulations of figures" (Montello et al. 1999, 516).

Realizing that spatial activity occurs at a wide range of scales, geographers have expanded the ideas of spatial ability to incorporate a variety of more complex skills that are utilized to answer a broader range of spatial questions (Self and Golledge 1994; Golledge and Stimpson 1997). Self and Golledge (1994) suggest a list of 15 unique spatial abilities that form the background necessary to succeed in a variety of disciplines. Figure 4 lists these various spatial abilities.

Through factor analysis of the way in which psychometric tests operationalize the definition of spatial ability, two primary components of spatial ability have been identified, and a third one has been suggested. The first of these is spatial orientation. This involves the ability to imagine how a visual stimulus would look from another perspective (McGee 1979). Golledge and Stimpson (1997) argue that this skill is important for geographic tasks such as map reading, image processing, wayfinding, and navigation. This skill is also utilized for spatial analysis performed in GIS. Users of GIS are required to adopt new perspectives of two- and three-dimensional objects, and use different frames of reference at different scales to make sense of shapes, patterns, or layouts that are represented graphically on the screen.

The second factor is spatial visualization. McGee (1979) identifies this as the ability to mentally manipulate, rotate, twist, or invert two- or three-dimensional visual ojbects. Golledge and Stimpson (1997) state that this ability is relevant to geography

Spatial ability	Representative disciplines
Think geometrically	Physics, mathematics, ecology, geography
Image complex spatial relations such as three-dimensional molecular structures or complex helices	Chemistry and biology
Recognize spatial patterns of phenomena at a variety of different scales	Geology and geography
Perceive three-dimensional structures in two dimensions and the related ability to expand two-dimensional representations into three-dimensional structures	Mechanical engineering, psychology, cartography
Interpret macro spatial relations such as star patterns or world distributions of climates or vegetation and soils	Astronomy and cartography
Give and comprehend directional and distance estimates as required in navigation and path integration activities used in wayfinding.	Aerospace and civil engineering
Understand network structures	Planning and transportation engineering
Perform transformations of space and time	Anthropology and history
Uncover spatial associations within and between regions or cultures	Anthropology, and sociology
Image spatial arrangements from verbal reports or writing	Literature and history
Image and organize spatial material hierarchically	Geography
Orient oneself with respect to local, relational, or global frames of reference	Aerospace, geography, and astromony
Perform rotation or other transformational tasks	Engineering, architecture, mathematics
Recreate accurately a representation of scenes viewed from different perspectives or points of view	Graphic art, cartography, and architecture
Compose, overlay, or decompose distributions, patterns and arrangements of phenomena at different scales, densities, and dispersions	Resource management, ecology

Figure 4. *Spatial Abilities and Disciplines in Which They Are Utilized (from Self and Golledge 1994 and Golledge and Stimpson 1997).*

because it is critical for comprehension and representation of geographic spaces. Albert and Golledge (1999) argue that this ability is helpful in the use of GIS because of the manner in which spatial objects in a GIS are manipulated on the screen.

The third factor is poorly defined and loosely referred to as spatial relations. Self and Golledge (1994) argue that this dimension is perhaps the most relevant to geography; however, it is also the dimension that has been explored the least by psychometric testing (Golledge and Stimpson 1997). Spatial abilities found in this factor include analyzing spatial distributions and patterns, shape layout, spatial hierarchy, linkages between specific objects within a visual configuration, spatial correlation, wayfinding in real-world environments, and orientation in real-world frames of reference (Golledge and Stimpson 1997). This dimension of spatial ability is closely tied to complex spatial ability that Golledge and Stimpson (1997, 157) identify as "the ability to compose, overlay, or decompose distributions, patterns, and arrangements of phenomena at different scales, densities, and dispersions." This ability is helpful in the use of GIS when it is necessary to identify specific features or hierarchies to which those features belong, the spatial associations between those features, and map overlay functions (Albert and Golledge 1999). These are analytical functions of GIS that users must understand in order to solve spatial problems with GIS.

Measuring Spatial Ability

Traditionally, spatial ability has been measured with pencil-and-paper tests. However, there are two limitations to measuring spatial ability with pencil-and-paper tests. First, they are not believed to account for the range of spatial activities and behaviors that take place at scales larger than the immediate surroundings of the person taking the test. Second, it is not clear how these scores relate to real world spatial activities (Montello, et al. 1999).

Another complication to the measurement of spatial ability is uncertainty in the role of gender. Gender differences in spatial ability tests have been noted for many years. Some even claim that this difference is one of the best documented and reliable findings of gender differences in the cognitive literature (Succuzzo et. al. 1996). McGee (1979) reports that studies from as early as 1944 demonstrate that males repeatedly out perform females on psychometric tests of spatial ability. This is especially true for timed tests that involve mental rotations (McGee 1979; De Lisi and Cammarano 1996; Saccuzzo et. al. 1996). These differences are the source of much controversy and debate with researchers, particularly within the last 30 years. A variety of theories have been postulated to explain these differences. According to Stumpf (1993, 828), notions about these differences

> … include biological approaches to stressing the importance of genetic, maturational, or hormonal factors or the role of differential cortical lateralization, as well as environmentalist approaches stressing the role of differential socialization experiences.

While there is evidence to link these theories to gender differences in spatial ability, no single theory has been proven to have greater influence than any of the others on the development of spatial skills.

In his analysis, Stumpf (1993) noted that studies are beginning to show that the long-term trend of gender differences in spatial abilities is decreasing. Golledge and Self (1994) are uncertain as to whether these differences even really exist. From their examination of multidisciplinary literature, they conclude that "on some tasks males often excelled, on some tasks females often excelled, but for many spatial tasks, no significant differences could be determined" (Golledge and Self 1994, 235). In a recent study of gender differences utilizing an array of spatial tasks resembling more realistic activities, the findings support the notion that either no difference between the genders exists or that those differences vary with scale and with the type of activity (Montello et al. 1999). These researchers conclude their discussion by stating that "clarification of the nature and magnitude of differences in abilities where they exist, and identification of areas where they do not exist, are important areas for continued research" (Montello et. al. 1999, 532).

Spatial Cognition and GIS

At this time, it is uncertain exactly how a user's spatial ability translates into an ability to utilize GIS; but utilizing GIS certainly requires the user to possess some level of spatial ability. With regard to the operations on spatial objects performed by uses of GIS, Couclelis (1992, 66) states that they

> … may be counted, moved about, stacked, rotated, colored, labeled, cut, split, sliced, stuck together, viewed from different angles, shaded, inflated, shrunk, stored, and retrieved and in general, handled like a variety of everyday solid objects that bear no particular relationship to geography.

Albert and Golledge (1999, 8) give a similar description of spatial operations utilized by GIS users. They state

> Spatial cognitive abilities allow the GIS-user to store into memory geographic information in the form of spatial objects or patterns of spatial objects and to perform mental operations on those spatial objects. These abilities are important for fundamental tasks such as remembering what a specific map looks like, determining if a spatial pattern exists among different spatial objects on a map, determining the appropriate sequence of GIS operations or commands to produce a desired outcome, or trying to visualize a 3-D topography from an alternative perspective.

These two descriptions of the spatial abilities employed by users of GIS assumes and incorporates many of the abilities identified by Self and Golledge (1994) as well as those described in the three factors of spatial ability identified from psychometric studies.

Studies of human spatial cognition tell us that human perception of space varies greatly depending on scale (Freundschuh and Egenhofer 1997; Golledge and Stimpson 1997). Freundschuh and Egenhofer (1997) designed a framework whereby studies of geographic spaces can be categorized. Their framework is built around the notion that the way in which individuals differentiate these spaces is two-fold: 1) the extent to which the space can be observed and 2) the degree to which humans interact with objects in that space. If the space can be viewed completely from a single vantage point and objects in that space can be directly manipulated, then it is characterized as small scale. If, on the other hand, the space cannot be viewed from a single vantage point, objects within that space cannot all be directly manipulated, and movement is required to experience the space, then it is characterized as large-scale. They suggest that GIS creates a misrepresentation of large-scale spaces because users are able to manipulate objects in a large-scale space as though they are manipulable objects found at a small scale space. In other words, GIS presents space as though it is independent of scale. However since pencil-and-paper tests require the mental manipulation of small objects on paper in a manner that is similar to the manipulation of objects in GIS, it is thought that these tests may be relevant to spatial abilities utilized in GIS (Albert and Golledge 1999).

In order to explain the way novices learn to use GIS, Nyerges (1995) suggests their spatial knowledge evolves through a series of mental models at three different levels. The three levels of knowledge described by Nyerges (1995) are declarative, procedural, and configurational. Declarative knowledge refers to factual knowledge, it is knowing about or knowing what. Procedural knowledge refers to knowing how to do something. The ability to perform a task or series of tasks in the appropriate sequence requires procedural knowledge. Configurational knowledge is knowledge of the relationship between distinct objects in geographic space. This includes knowledge about such things as the angles between road junctions, the location of one object relative to other locations or relative to a reference grid. In addition, Bednarz (1997) describes a fourth level of knowledge relevant to using GIS. Conditional knowledge refers to knowing how and when, that is in what conditions, to apply the other types of knowledge. Within GIS, knowing that an analytical function such as buffering exists is declarative, knowing the steps to perform the buffering function is procedural, knowing the result of the buffering operation in relation to the original object is configurational, and knowing if a problem requires the buffering function is conditional knowledge.

Individual Differences

Nyerges (1993) asserts that these levels of spatial knowledge reside with two domains: problem-domain knowledge and tool-domain knowledge. Problem-domain knowledge is the conceptual knowledge required to solve a spatial problem. Tool-domain knowledge is the ability to solve a spatial problem within the context of GIS. He concludes that becoming proficient in the use of GIS requires complex interaction within and between these various abilities and knowledge.

Every individual has different abilities, experiences, knowledge, and assumptions about the world. As such, their conceptions of space will vary as well as well as their conceptions of space in a GIS. Mark (1993) points out that human conceptions of space and the relative importance of those conceptions vary not only by individual, but also by culture, language, and disciplinary training. Mark (1993) concludes that the variability of these human factors of spatial cognition should be considered when designing the user interface of a GIS.

Medyckyj-Scott and Blades (1992) explain that GIS software forces the user to think of space in terms of nodes, arcs, polygons, or rectilinear grids. These are representations of space that may not correspond with the user's conceptualization of space. They believe that the consequence of this disconnect in spatial representation is that the user will only learn to use a small number of operations which will ultimately limit the user's ability to exploit the GIS in its full functionality.

Human-Computer Interaction

Learning and Attitudes About Computers and Software

A second cognitive factor is the ability to interact with computers. Because GIS is primarily performed on a computer, an understanding of the functioning of a computer is vital. GIS requires that users acquire, store, manipulate, analyze, and generate the final product—all within a digital domain. Thus, part of the process of learning to use

GIS is learning how to operate new systems of software and hardware. Operating the software, maintaining databases, and making sure that the hardware is functioning properly are all aspects of human-computer interaction with GIS.

Human-computer interaction (HCI) is the study of the interactions between systems of people and systems of computers (Long 1989). Because of the field's nature, HCI has been divided into two bodies of research, one concerning the human component and one concerning the computer system. The research on the human component in computer interactions is further broken down into studies of physical factors, and cognitive factors (Turk 1995). Physical factor studies investigate physical ergonomics, interface design, and documentation, or the way humans physically interact with the computer, while the cognitive factors (increasingly being referred to as cognitive ergonomics) investigate the ways people learn about interacting with the computer system (Turk 1995).

Studies in the human aspect of HCI have identified three aspects that have an impact on users' ability to learn how to use the computer. These include the psychological aspects (i.e. attitudes about computers), the cognitive aspects (i.e. prior achievement and computer aptitude), and the extent of prior experience with computers (Levine and Donitsa-Schmidt 1997). Kay (1993) concludes that while these factors are relevant, their presence is not sufficient to help someone become proficient in computers. According to Kay (1993), there must be a strong will and a need , that is, a motivation, for students to broaden their knowledge and skills in the use of computers before significant learning will take place.

Although there is no dispute about the significance of these three factors, findings from studies of these factors and their relationship to computer learning have been inconsistent (Jawahar and Elango 1998). Kay (1993) explains that there has been research on a wide assortment of issues that underlie computer learning. Given this diversity of issues, or constructs, it becomes difficult to identify common themes within instruments used for measuring these constructs. It has also been suggested that the numerous methods used to measure these constructs increased the variability of individual differences (Szajna and Mackay 1995). Finally, it has also been argued that a lack of clarity, or specificity, of these constructs may be partially responsible for the inconsistency of results (Bandalos and Benson 1990; Jawahar and Elango 1998). For example, “attitudes toward working with computers” is much more specific than “attitudes toward computers” and a few terms such as “computer attitude” and “computer anxiety” or “computer aptitude” and “computer achievement” have often been used interchangeably.

Although a number of other factors have been found to correlate with learning to use computers, it is interesting to note that several studies have found that spatial ability can be a predictor of computer use (see Gomez, et. al. 1986; De Lisi and Cammarano 1996; Saccuzzo, et. al. 1996). This relationship has been found in editing tasks, information-search tasks, and skill in video games. De Lisi and Cammarano (1996) found that practice with video games that require mental rotation increased scores in spatial ability tests and decreased the gender difference on those tests.

Human-Computer Interaction and GIS

The cognitive aspects of HCI and GIS have not received a great deal of attention. Most of what has been written is focused on methods and strategies for teaching GIS software covered earlier in this chapter. Aside from that thread of research, human factors of HCI and GIS have focused mainly on the user-computer interface and ways to enhance users' ability to interact with that interface. As with studies of spatial cognition, this research is primarily theoretical and conceptual with very little empirical evidence to support the assertions of the authors.

Because of the complexity of GIS and its non-intuitive interfaces, learning to use GIS software has been a source of anxiety for beginners. Even though the interface between users and GIS software continues to improve, the lack of a friendly, intuitive interface continues to be a persistent frustration within the community of GIS users (Nyerges 1993). As a result of the complicated interface, the cognitive demands placed on the learner to understand the interface, GIS is perceived as a tool that, while useful, is difficult to master (Freundschuh and Gould 1991; Turk 1993).

Davies and Medyckyj-Scott (1995, 124) suggest that the design and configuration of the GIS hardware and software have a low level of "cognitive compatibility," that is, "the degree of compatibility between the user's mental model of the way the system works and the conceptual model that actually underpins the system and its user interface." These authors propose that cognitive compatibility can be considered at four levels: conceptual, semantic, syntactic, and physical interaction. It is at the conceptual level that the user's representation of the world is matched up with the data model used in the GIS. The semantic level includes the data structures and commands used to accomplish the goals. The syntactic level includes the design and the control display representations, modes of interaction, and syntax of operations. The physical interaction level is characterized by actions such as pressing keys on the keyboard or using the mouse to point, click, and drag. They note that the lack of the users' control over much of the GIS interface places significant cognitive demands on users and therefore frustrates their efforts to use the computer system.

Turk (1993) suggests that the GIS computer system should share the cognitive responsibility for decision making. He reasons that the use of digital maps is similar to using paper maps, which place 100 percent of the cognitive responsibility for decision-making on the user and none on the computer. At the other extreme, an artificial intelligence system places 100 percent of the cognitive responsibility on the computer and none on the user. Using a GIS falls somewhere between these two extremes. A GIS can provide a greater amount of information than a paper map, but the user is required to determine the type of spatial analysis to perform with the GIS, which increases the user's cognitive responsibility. However, this responsibility can be shared by the computer if the interface is designed to facilitates efficient processing the presentation of information. While Turk (1993) acknowledges that improvements have been made to the GIS interface, he laments that without a greatly increased emphasis on studies of HCI, the GIS interface will be extremely slow to improve.

Problem Solving

Geographers have long been concerned with finding solutions to spatial problems. Golledge and Stimpson (1997, 1) note that geographers have studied spatial problem solving by individuals, organizations, institutions, and society in such tasks as "…deciding where to locate activities, where to perform tasks like shopping, where to live, and how people develop knowledge about the operational environment that enables decision making to occur in geographic space." GIS is a tool that can facilitate such spatial decision-making processes.

Cognitive scientists define problem solving as a set of mental operations with the goal of adapting to either internal or external challenges or demands (Heppner 1988). As individuals' personal experiences expand, they develop general beliefs about themselves and their abilities, forming a set of expectations about the way they approach and solve problems. Bandura (1986) refers to this aspect of self-appraisal as efficacy. Efficacy, in turn, affects motivation, behavior, thoughts and emotional reactions to problem solving situations. Thus problem solving entails the dimensions of confidence/anxiety toward solving a problem, willingness to confront/avoid a problem solving situation, and perceived control over finding the solution to a problem.

Information processing is the dominant theory in educational research (Jonassen 1997). According to Gagne (1985), this model of problem solving involves the interaction of declarative knowledge, procedural knowledge, and the processing of new information in short-term memory. This theory is represented by problem solving models that utilize a means-ends method of analysis. Another way of looking at this is to conceptualize problem solving as the act of reducing the differences between pre-existing knowledge and the solution to the problem (Anderson 1993). Problem solving through means-ends analysis involves three generic steps. The process begins when the learner perceives the problem and generates a mental representation of the problem. The learner then searches for possible solutions that can be implemented and tested. The process of searching for possible solutions continues until a successful solution has been identified. The IDEAL (identifying, defining, exploring, acting, and looking back) model is representative of this process (Jonassen 1997).

Golledge and Stimpson (1997) present a form of the means-ends model of problem solving when they describe behavior that motivates spatial decision-making. They suggest that the problem is perceived through a stimulus. This is followed by a decision-making response which is then followed by a behavioral choice. Finally, these steps are evaluated providing feedback for future decisions.

Problem Solving With GIS

Since its inception, GIS has been touted as a tool to help find solutions to spatial problems. The way problems are solved is not generally discussed in the literature in terms of the mental processes, but rather in terms of the computer processes. It is often assumed that the person utilizing the GIS is capable of solving a problem but what is not clear is how that person formulates, visualizes, and processes the problem from beginning to end. Most of the published research on problem solving and GIS has focused on the technical aspects of solving a specific problem and the processes utilized in resolving issues such as data collection, data format, choice of analyses, and policy considerations for implementing the solution.

For users of GIS, the cognitive process of problem solving is necessary because GIS is typically utilized to develop the solution to a spatial problem or set of spatial problems (Nyerges 1993). Successful use of GIS entails integration of spatially referenced data in a problem-solving environment (Cowen 1988). This is not to suggest that the GIS solves spatial problems but rather, that it is a tool to support the spatial problem solving process. A GIS extends human memory with a database management system, aids in spatial analysis through rigorous computation, and enhances visualization of large amounts of information through map display (Nyerges et al. 1995). While a GIS provides a means for solving the problem, users must have the ability to envision what spatial elements and analytical tools of GIS are necessary to generate a decision or an optimal solution to the problem through logic and reasoning skills (Nyerges 1993).

Audet and Abegg (1996) examined the difference between expert and novice users of GIS. They found significant differences in the way the two groups utilized GIS to solve a problem. In their study, these researchers identified three strategies for solving problems with GIS: trial and error, spatial querying, and logical querying. The novices typically employed either the trial and error or spatial querying strategy whereas experts typically used the logical querying strategy. They also found that as novices progress through the problem set, they began to utilize higher-order thinking skills to arrive at their solutions.

Geographic Knowledge

As the name suggests, geographic information systems are linked with an understanding of geography. Knowledge of geographic concepts and principles is considered prerequisite to using GIS effectively. Because geography is the study of space and spatial relationships, an understanding of geographic principles is necessary if users are to appropriately implement GIS technology. Walsh (1992, 55) states:

> … to know GIS one must first know geography … geographic knowledge regarding bio-physical and socioeconomic systems and the landscapes they produce relate to the ability of GIS analysts to interpret findings and make effective use of the analytic power of GIS.

Whereas there are no discussions in literature about how much geographic knowledge is necessary to operate a GIS, there are many warnings about implementing GIS without an adequate level of geographic knowledge. King (1991) is concerned that students' interest in learning GIS will supersede interest in learning basic geographicy. He stresses the importance of balancing technical classes with other geography classes.

As GIS technology has improved, many of the analytical operations of GIS have become deceptively simple. By simply clicking a few buttons, it is possible to quickly answer geographic queries. The danger in this simplicity is that users can produce irrelevant and erroneous solutions if they fail to understand the subject to which the GIS is being applied (Walsh 1992). According to the NRC (1997, 62),

> Users [of GIS] need considerable background knowledge of the subject matter to which [the GIS is] being applied, as well as an understanding of the analytical operations available on the systems, in order to know what questions to ask, the relevant variables to invoke, and how to recognize nonsensical procedures and answers.

According to White and Simms (1993), without the prerequisite knowledge the function of GIS is transformed from a tool of spatial analysis to a magic box.

CHAPTER III

METHODOLOGY

This chapter describes the procedures utilized in this research. This study examines the relationship between the cognitive skills and abilities of the participants and their success in the GIS course. The purpose for this study is described first, followed by a description of the setting and sample, the research design, the procedures, and finally an examination of the way that GIS courses are structured at other universities. The final part is included to enhance the generalizability of the findings from this research.

Purpose of the Study

The two key objectives for this study are: 1) to investigate the cognitive skills and abilities of students enrolled in an introductory university course of GIS and 2) to determine if there is a significant relationship between the cognitive factors and the students' success in the class. A secondary purpose of this study is to examine demographic characteristics of the learners to determine if sub-populations within the sample score differently on these cognitive measures. Learner characteristics of interest include gender, race, class level (junior, senior, or graduate), and field of study.

A number of articles have been published in recent years proclaiming the benefits of utilizing GIS in the classroom (Walsh 1988; King 1991; White and Simms 1993; Keiper 1999; Kerski 2000). These benefits include such things as improvements in students' spatial ability and problem solving skills or greater satisfaction in learning geography. Unfortunately, many of these discussions are based on the personal experience of instructors and anecdotal discussions with students, but not on empirically verified results (Baker and Bednarz 2003). This research will attempt to demonstrate empirically that a class in GIS can enhance the learner's spatial ability, problem solving skills, computer ability, and attitudes about geography.

Setting and Sample

The participants in this study were students taking the "Principles of GIS" course at Texas A&M University during the fall and spring semesters of the 2000-2001 academic year. GEOG 390, The Principles of GIS course, is taught every semester in the Geography Department. The course description states the course covers the "Basic concepts of design, planning and implementation of geographic information systems." Junior or senior classification is listed as the prerequisite. GEOG 390 is a three-hour course; students attend three hours of lecture and two hours of lab each week. The content of the lectures is conceptual and theoretical. The labs are designed to give the student practical experience in applying the principles learned in the lecture by using GIS software.

The study was conducted at the main campus of Texas A&M University in College Station, Texas. Institutional Review Board (IRB) procedures were followed to ensure the ethical treatment of human subjects. All of the participants signed "Informed

Consent Documentation" indicating their participation in the research was voluntary. The informed consent document is included in Appendix A

Research Design

Objective One

The first purpose of this research was to measure the relationship between students' pre-existing cognitive skills and determine if these skills improved after participating in the class. The hypotheses for this aspect of the research are stated as follows:

H_0: Students' scores on the tests of cognitive skills will not be different after completing the class.

H_1: Students' scores on the tests of cognitive skills will be greater after completing the class.

There are three questions that operationalized the procedure to tests these hypotheses.

1) What are the students' scores on tests of cognitive skills at the beginning of the semester?
2) Are the students' scores on tests of cognitive skills statistically significantly greater at the end of the semester than at the beginning of the semester?
3) Are the scores of the different sub-populations statistically significantly different?

To answer these questions, a one-group, pretest-post test experimental design was implemented. According to Gall et al. (1996, 491) this design

> … involves three steps: 1) administration of a pretest measuring the dependent variable; 2) implementation of the experimental treatment (independent variable) for participants; and 3) administration of the posttest that measures the dependent variable again. The effects of the experimental treatment are determined by comparing the pretest and posttest scores.

In this study, there were five dependent variables: spatial ability, learning style, computer aptitude and anxiety, problem solving style, and attitudes and beliefs about geography. The experimental treatment for this research was the GIS instruction received by the students as a part of this class.

Objective Two

The second purpose of this research was to examine the relationship between the measured cognitive factors and the students' success in the class to determine if this is a significant relationship. The hypotheses for this aspect of the research are:

H_0: The correlation between the participants' scores on the tests of cognitive skill and their success in the class is statistically insignificant.

H_1: The correlation between the participants' scores on the tests of cognitive skill and their success in the class is positive and statistically significant.

There are four questions that operationalized the procedure to tests these hypotheses:

1) How strong is the relationship between the factors measured by each test and the students' success in the class?

2) Can any of the factors act singly as a predictor of the students' success in the class?

3) Is there some combination of factors that can act as a predictor of students' success in the class?

4) Does success in the class vary between the different sub-populations?

To answer these questions, correlation coefficients were calculated and tested for significance. For the purposes of this study, success was measured in three ways, all related to students' final grade in the class: lecture grade, lab grade, and final project grade. Each measure of student success was correlated with each of the tests for dependent variables listed previously as well as the variables of gender, race, class level, and major.

Procedures

Since cooperation with the course instructor was vital to this study, the researcher met with each professor before the semesters began. During this meeting, the researcher described procedures and discussed the potential impact the project might have on the class. Permission was granted by each course instructor for the researcher to observe and interact with students in the class and computer lab for each semester.

On the first day of class each semester, the researcher gave the students a brief introduction to the project and asked them to participate in the study. Informed consent documentation, which explains the purposes and expectations of the study and issues of anonymity and confidentiality were distributed. At this point students indicated whether they would participate in the study by signing the informed consent documentation. Gift certificates to a popular local restaurant, donated to the researcher, were used as an incentive to increase participation.

Methods

During the next two weeks, pre-tests were administered during the lab portion of the class and the students were allowed to take home some of the surveys and complete them during the next week. This was done in an effort to reduce test fatigue. During the first lab session, the participants completed the demographic questionnaire, the computer understanding and experience scale, and the computer anxiety scale. At that same lab session, the participants were given the geography attitude measure, the problem-solving inventory, and the learning style inventory all of which they were allowed to take home and complete. During the second lab session, the card rotation test, hidden figures test, and the Vandenberg mental rotation test were completed. Post-tests of the computer understanding and experience scale, and the computer anxiety scale were administered during the lab session of the 13th week of the semester. At that time students again were allowed to take home and complete the geography attitude measure, the problem-solving inventory, and the learning style inventory. The card rotation test, hidden figures test, and the Vandenberg mental rotation test were completed during the lab sessions of the 14th week of the semester. The interval between the tests was approximately 10 weeks.

Interviews of participants were also conducted to gather evidence to support the findings from the quantitative analysis. Fourteen participants were randomly selected for interviews during the lab portion of the class after they finished their work for that particular session. Each of the participants was interviewed once and the interviews lasted no longer than 10 minutes. The interview sessions attempted to determine the participants' perceptions of GIS, their perceived success in the class, their GIS learning strategies, and the approaches they used to formulate and solve spatial problems.

Measurement Instruments

To measure the dependent variables (learning style, spatial ability, computer aptitude and anxiety, problem solving style, and attitudes and beliefs about geography) self report, survey instruments with known reliability and established construct validity were used for each of the areas. Instructional procedures for administering and scoring each survey were strictly followed. A description of each instrument follows. Because most of these are copyrighted forms, only the Computer Aptitude and Anxiety survey and the Geography Attitude Measure are included in the Appendices.

Learning Style Inventory

The Learning Style Inventory (LSI) is designed to identify differences among individual learning styles and corresponding learning environments (Kolb 1999). This is an untimed survey that can be completed and self-scored in about 15 minutes. The respondent is asked to rank-order four sentence endings (from 1, least like you, to 4, most like you) for 12 items that provide scores corresponding to the four learning scales—Concrete Experience (feeling), Reflective Observation (watching), Abstract

Conceptualization (thinking), and Active Experimentation (doing). Two combination scores are also obtained that indicate the extent to which the individuals emphasize action over reflection (AE-RO) and the extent to which they emphasize abstractness over concreteness (AC-CE). The four basic scales and two combination scores show very good internal reliability as measured by Cronbach's α (n=268). See Table 3-1 for a breakdown of these scores.

Table 3-1. *Reliability Measures for the Learning Style Inventory (from Kolb and Smith 1996).*

Measure	Reliability
Concrete Experience (CE)	0.82
Reflective Observation (RO)	0.73
Abstract Conceptualization (AC)	0.83
Active Experimentation (AE)	0.78
Abstract-Concrete (AC-CE)	0.88
Active-Reflective (AE-RO)	0.81

Because geography is divided into human and physical geographers, Healey and Jenkins (2000) cite studies where geographers are found to range across all of the scales. Healey and Jenkins (2000) suggest that human geographers are more concrete and active and physical geographers are more abstract and reflective. It is expected that the learning style of students enrolled in the GIS class will be more closely related to physical geographers.

Problem Solving Inventory

The Problem Solving Inventory (PSI) is an instrument used to "assess an individual's perceptions of his or her own problem-solving behaviors and attitudes" (Heppner 1988, 1). The PSI is designed to measure the subjects' perception of their own problem-solving capabilities but not their actual problem-solving skills.

The PSI is an untimed survey that can be completed in about 15 minutes. This instrument consists of 35 statements, three of which are not scored because they are described as research items. Each statement is ranked on a Likert scale that ranges from 1 (strongly agree) to 6 (strongly disagree). The total score is obtained by adding the scores of all responses. Low scores are associated with a positive appraisal of problem-solving ability. Numerous studies have shown that subjects with lower scores "rated themselves as more motivated to solve problems, more likely to expect success, to be less impulsive and avoidant and more systematic and persistent, … and more likely to learn problem-solving by observing others" (Heppner 1988, 12).

Three factors of the PSI have been derived through factor analysis. Problem-Solving Confidence (PC) is defined as self-assurance while engaged in problem-solving activities. Approach-Avoidance Style (AA) is a general tendency to approach or avoid problem-solving activities. Personal Control (PC) indicates the extent to which individuals believe they are in control of emotions and behaviors while solving problems. Table 3-2 shows the reliability measures for the three scales and for the Total PSI.

Table 3-2. *Reliability Measures of the Problem Solving Inventory (from Heppner 1988).*

Measure	**Reliability**			**Test-Retest**		
				2 weeks	3 weeks	2 years
	N=150	*N*=66	*N*=146	*N*=31	*N*=64	*N*=29
Problem-Solving Confidence	0.85	0.78	0.85	0.85	0.78	0.65
Approach-Avoidance Style	0.84	0.90	0.86	0.88	0.77	0.61
Personal Control	0.72	0.74	0.73	0.83	0.81	0.44
Total PSI	0.90	0.90	0.91	0.89	0.91	0.60

Computer Aptitude and Anxiety

Two surveys regarding computers were administered. The first is the Computer Understanding and Experience Scale (Potosky and Bobko 1998), and the second is the Computer Anxiety Scale (Bandalos and Benson 1990). These particular instruments researcher to combine and administer them as a single instrument. They are individually described in detail below.

Computer Understanding and Experience

The Computer Understanding and Experience Scale (CUE) is a self-report measure designed to assess basic computer "know-how." The CUE also includes a number of questions to asses "knowledge of a variety of general computer uses in order to determine the breadth of one's computer experience" (Potosky and Bobko 1998, 341). This is an untimed survey that can be completed in about five minutes. The instrument consists of 20 statements that are ranked on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). The total score is obtained by adding the scores of all responses. A high score suggests that an individual is generally good at using computers. The internal reliability for the CUE, α=.93 (n=279), is very high.

Computer Anxiety Scale

The Computer Anxiety Scale (CAS) is structured much like the CUE, but it measures the respondent's feelings of anxiety and confidence toward computers and their use (Bandalos and Benson 1990). This is an untimed survey that can be completed in less than five minutes. Ten statements are ranked on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). A high score suggests that an individual generally feels very confident in their ability to do work using computers. The internal reliability for the CAS, α=.96 (n=375), is very high.

Geography Attitude Measure

The Geography Attitude Measure (GAM) is a 15-item, semantic differential-scaled instrument. Responses on a semantic differential scale are rated in a similar manner to a Likert scale. Rather than using an agreement/disagreement scale, the semantic differential requires the participant to rate an object (in this case, geography) along a seven-step scale between two bipolar adjective such as good-bad or natural-unnatural (Gable and Wolf 1993). Items are scored from 1 to 7 with the negative adjective having the low values. For example, the participant chooses whether they think that geography is extremely bad (value = 1), moderately bad (2), slightly bad (3) neither good or bad (4), slightly good (5), moderately good (6), or extremely good (7).

The scores are summed with a maximum possible total score of 105. A high score indicates the participant has a positive attitude toward geography. The instrument used in this study was modified slightly from an instrument developed by Kay (1993). The modified instrument was pilot tested with a group of four graduate students to ensure face validity. Discussions and analysis of the pilot study resulted in some modifications to the scale.

Spatial Ability Tests

Three standard paper and pencil tests were administered to measure spatial ability: Hidden Pattern Test (Ekstrom et al. 1976), Card Rotation Test (Ekstrom et al. 1976) and the Vandenberg Mental Rotations Test (Vendenberg and Kuse 1978). Reliability on these tests are high, ranging from .80 to .91. See Table 3-3 for estimates of the internal consistency. These tests were chosen because they have been used extensively in research studies, the method of administration and scoring is identical on all three tests, and activities of the respondent are similar to those performed when using a GIS. These tests assess both the visualization and orientation dimensions of spatial ability using two-dimensional and three-dimensional figures. The tests are timed and broken into two, three-minute sections. The total time required to complete these surveys is approximately 12 minutes which includes time for instructions and practice. Scoring for each test is the number of incorrect items subtracted from the number of correct items.

Table 3-3. Reliability Measures for the Spatial Abilities Tests (from Ekstrom et. al. 1976 and Vandenberg and Kuse 1978).

Measure	Reliability
Card Rotations	0.83 (n=99)
Hidden Pattern Test	0.81 (n=189)
Vandenberg Mental Rotations	0.88 (n=3,268)

Card Rotation Test

This test consists of 20 items in 10 sets of eight items for a total of 160 items. Each item gives a drawing of a card cut into an irregular shape. To its right are eight other drawings of the same card, sometimes merely rotated and sometimes a mirror image. The person taking the test indicates whether the card is the same (merely rotated) or different (mirror image). This test consists of two parts, each of which must be completed within three minutes. The score for this test is the number of correct responses.

Hidden Pattern Test

This test consists of 400 items. Each item consists of a given geometrical pattern in some of which a single reference figure is embedded. The task is to mark, for each pattern, whether or not the reference figure is embedded. This test consists of two parts, each of which must be completed within three minutes. The score for this test is the number of correct responses.

Vandenberg Mental Rotations Test

This test consists of 20 test items in five sets of four items. Each item presents a complex three-dimensional criterion figure, two correct alternative and two incorrect ones. The two correct figures are identical to the criterion figure but are shown in a rotated position. The two incorrect figures are either a rotated mirror image of the criterion figure or a different figure altogether. The subject indicates which figures are the rotated, identical figures. This test consists of two parts, each of which must be completed within three minutes. The score for this test is the number of correct responses.

Data Analysis

Quantitative data yielded by scores on the surveys and the lab, lecture, project, and final grades were entered into a spreadsheet and formatted for use in the Statistical Package for the Social Sciences (SPSS). The hypothesis and research questions were investigated using descriptive statistics, *t*-tests, analysis of variance, product-moment correlation, and multiple regression. Results from these analyses will guide the use, if necessary, of post-hoc analysis. Finally, data obtained from interviews, lecture observation, lab observation, and student-generated materials were analyzed and used in an attempt to qualitatively clarify and verify findings from the results of the quantitative analysis.

GIS Instruction at Other Universities

Purpose of Study

Since this study is limited to GIS instruction at Texas A&M University, a study that examined GIS instruction at other institutions was also conducted. The class structure and organization of the GIS classes taught at Texas A&M University was compared to similar courses taught at other institutions. The goal of this research is to provide context for GIS instruction and thereby enhance the generalizability of the findings of the research from the first study. While the particular teaching methods found in GIS classes at other institutions was not examined, the manner in which those classes are structured may provide insight into the manner in which the classes are taught. This research examined syllabi from a wide range of colleges and universities in an effort to determine how GIS classes operate in different settings.

Research Design

The purpose of this research is to examine the way that instructors of GIS at other institutions structure their classes. This apect of the research strives to answer six questions about GIS instruction at other institutions:

1) What are the prerequisites for GIS classes?
2) What are the credit hours assigned to the GIS classes?
3) What are the required textbooks?
4) What are the primary and secondary software packages are utilized in these classes?

5) How are the students evaluated in these classes?

6) What are the major topics discussed and the percent of time allocated to these topics?

Procedures

To obtain syllabi for GIS classes from other institutions, the world-wide web was utilized. As the ease by which material can be delivered to students has increased, so has the number of professors putting their course materials on-line. Due to the ease of access, 39 sample syllabi were obtained from the internet. Since GIS requires a high level of familiarity with computer technologies, it is assumed that those professors who put their syllabus on the internet will not structure their classes differently than those who do not.

Methods

Universities were identified from listings in the Higher Education Directory at the Yahoo internet portal (http://dir.yahoo.com/Education/Higher_Education/Colleges_and_Universities/By_Region/U_S_States) and the ESRI online database of academic GIS programs (http://gis.esri.com/university/onlinedb.cfm). In addition to the syllabi, the course description from each university's on-line catalog was also collected. To guide the syllabi selection process the following criteria was developed:

1) Only institutions operating on a semester system would be utilized;

2) Only GIS classes that were identified as introductory would be utilized;

3) Only GIS classes that were taught in a geoscience department would be utilized.

Data Analysis

The research questions posed in this study will be answered through the use of a content analysis procedure. According to Gall, et. al. (1996), the process of conducting a content analysis includes these five generic steps: 1) identify relevant documents; 2) select a sample of documents to analyze; 3) develop a coding procedure; 4) conduct the analysis; and 5) interpret the results of the analysis. The coding procedure requires qualitative analytic techniques to create the coding categories. Since the results of this study are descriptive in nature there is no quantitative analysis beyond statistics describing the frequencies of responses in the different coded categories.

CHAPTER IV

RESULTS

This chapter describes the results of the investigation. The sample of students who participated is described first. Then each of the hypotheses and research questions is addressed.

Sample

Eighty-four students began the course (36 in the fall and 48 in the spring), nine withdrew from the course, and five chose not to participate in the study. Over the two semesters, the remaining 70 students participated in at least one portion of the study. The overwhelming majority of participants were white (77.2 percent). The ethnicity of the remaining participants was Hispanic (12.9 percent), Asian (7.1 percent), Black (1.4 percent), or Other (1.4 percent). Because of the low number of participants who categorized themselves as “Asian” and “Black,” they were grouped with “Other” for the analysis. Male students comprised 71.4 percent of the participants and females made up 28.6 percent. Table 4-1 summarizes the demographic data as self-reported by the participants.

The majority of participants of this study were seniors (68.6 percent). The remaining participants were either juniors (18.6 percent) or graduate students (12.9 percent). Geography made up the largest proportion of majors (54.3 percent). Students majoring in Geology, Rangeland Ecology & Management, and Wildlife & Fisheries

Table 4-1. Demographic Characteristics of the Participants.

Race	Female (%)	Male (%)	Total (%)
Asian	--	5 (7.1)	5 (7.1)
Black	1 (1.4)	--	1 (1.4)
Hispanic	2 (2.9)	7 (10.0)	9 (12.9)
White	16 (22.9)	38 (54.3)	54 (77.1)
Other	1 (1.4)	--	1 (1.4)
Total	20 (28.6)	50 (71.4)	70

Science constituted the remaining 8.6 percent of the participants. Majors with fewer than three participants were categorized as Other. There were a total of 14 participants in category of Other including two in each major of Planning, Bioenvironmental Sciences, Agricultural Engineering and one in each major of Sociology, Renewable Natural Resources, Plant Physiology, Information & Operations Management, Environmental Design, Architecture, and Agronomy. One student who did not provide a major is also included in the category of Other. Table 4-2 summarizes the educational background as self-reported by the participants.

Table 4-2. *Educational Background of the Participants*

Major	**Junior (%)**	**Senior (%)**	**Graduate (%)**	**Total (%)**
Geography	6 (8.6)	27 (38.6)	5 (7.1)	38 (54.3)
Geology	2 (2.9)	3 (4.3)	1 (1.4)	6 (8.6)
Rangeland Ecology & Mgmt.	1 (1.4)	5 (7.1)	--	6 (8.6)
Wildlife & Fisheries Science	2 (2.9)	4 (5.7)	--	6 (8.6)
Other	2 (2.9)	9 (12.9)	3 (4.3)	14 (20.0)
Total	13 (18.6)	48 (68.6)	9 (12.9)	70

Instructional Setting

This study took place over two semesters with two different professors. The GIS classes met twice a week for lectures and once a week for labs. The entire class met in a large classroom for lectures. Lectures provided a theoretical and conceptual background in GIS. Both professors used a direct lecture technique with an overhead projector to make their notes easily visible to the students. The professors also placed their notes on their personal homepages where they could be accessed and reviewed by the students. The lab sessions provided hands-on, computer-based software experience. Students met in groups of 12 in a computer lab were a graduate teaching assistant would oversee the activities. Each week the students would complete a practical exercise. They were given a problem with a set of instructions that would guide them through a series of GIS operations. The exercises were simple and straight forward at the beginning of the term and became more complex as the semester progressed and their skill at operating the GIS software increased. By the end of the semester, students were expected to develop and implement an independent project to demonstrate their proficiency in using GIS. The final grades were based on examinations on lecture materials, grades on lab exercises, and the grade on the final project.

Because the participants were spread over two semesters with different instructors, I tested to determine if there was a semester or instructor effect. Such an effect would be indicated by a difference in the students' overall success in the class as determined by the student's final grade. An independent samples *t*-test was used to test if there was a difference in the overall success of the students enrolled in the different semesters. The *t*-test revealed no significant success differences ($p>0.05$) with respect to the semester enrolled. Therefore, participants from both semesters were treated as a single sample. Table 4-3 summarizes the results of the *t*-test.

Table 4-3. *Summary of Independence of Success by Semester*

Semester Enrolled	*Mean*	*sd*	*n*	*df*	Sig.
Fall 2000	81.72	11.067	29	68	0.101
Spring 2001	85.26	6.771	41		

Quantitative Analysis

Objective One

The hypotheses for this objective of the research are stated as follows:

H_0: Students' scores on the tests of cognitive skills will not be different after completing the class.

H_1: Students' scores on the tests of cognitive skills will be greater after completing the class.

Since the alternate hypothesis stated that the scores would be improved at the end of the semester, a one-tailed, paired-sample *t*-test was computed for scores on each of the cognitive measures to test the hypothesis. Table 4-4 summarizes the results of these *t*-tests. There was a failure to reject the null hypothesis for the cognitive measures of Computer Use and Experience (t=1.723), Card Rotation (t=6.105), Hidden Figures (*t*=5.549), and Vandenberg Mental Rotation (*t*=2.083). The sample size indicated for each measure is the number of students who completed both the pretest and posttest for each of the measures. The variation in the sample size is due to the number of survey forms administered and limitations placed on the researcher regarding the times when the surveys could be administered. As such, not all participants were able to complete both the pre-test and post-test, leading to the variation in sample sizes. A logistical error in the administration of the post-tests resulted in the low number of participants completing both portions of the Geography Attitude Measure.

Table 4-4. *Descriptive Statistics for all Cognitive Measures*

Cognitive Measure	*n*	*Pretest (sd)*	*Posttest (sd)*	*t*
Computer Use & Experience	44	83.98 (11.042)	86.75 (11.771)	1.723*
Computer Attitude	44	37.50 (8.706)	36.23 (8.915)	-1.185
Geography Attitude	18	88.06 (14.526)	86.94 (18.713)	-0.548
LSI AC-CE	38	5.05 (10.384)	6.71 (10.603)	0.988
Confidence	38	26.03 (7.886)	25.74 (8.126)	0.239
Approach/Avoidance	38	46.24 (9.539)	48.53 (10.827)	-1.523
Card Rotation	59	111.86 (32.526)	124.93 (28.496)	5.632**
Hidden Figures	53	219.13 (54.163)	264.92 (63.469)	5.549**
Vandenberg Mental Rotation	57	37.12 (15.808)	40.88 (19.105)	2.083*

*$p<0.05$ **$p<0.01$

The second part of this objective was to determine if gender, race, class, or field of study affected student performance on the assessments. The mean for subpopulation pre-test scores of each of the cognitive measures were compared using one-way analysis of variance. Since the ANOVA test only indicates a difference between group means, post-hoc comparisons were made using the Scheffe technique. The Scheffe method was utilized because of the unequal size of the groups. The results of these tests are summarized in Tables 4-5, 4-6, 4-7, and 4-8 for the factors of gender, race, class, and major respectively.

For gender, there is a failure to reject the null hypothesis for all of the cognitive measures except Computer Use and Experience (*F*=11.187) and the Computer Attitude Measure (*F*=3.090). For Computer Use and Experience, males scored higher demonstrating a greater level of computer proficiency. Males also scored higher on the Computer Attitude Measure meaning the men had a more favorable attitude toward computers. For race, there is a failure to reject the hull hypothesis for all of the cognitive measures. For class, there was failure to reject the null hypothesis for all of the cognitive measures. For field of study, there was a failure to reject the null hypothesis for all of the cognitive measures except the Geography Attitude Measure (*F*=3.389). On this measure, geography majors scored nearly 15 points higher than majors categorized as Other. The post-hoc analysis, however, revealed that this was not a statistically significant difference between these two groups (*p*=0.065).

Objective Two

The hypotheses for this aspect of the research are:

H_0: The correlation between the participants' scores on the tests of cognitive skill and their success in the class is statistically insignificant.

H_1: The correlation between the participants' scores on the tests of cognitive skill and their success in the class is positive and statistically significant.

Table 4-5. *ANOVA Results on Pretests for Gender.*

Cognitive Measure		*df*	***Sum of squares***	***Mean of squares***	***F***
Computer Use	*Between Groups* *Within Groups* *Total*	1 68 69	1632.516 9922.970 11555.486	1632.516 145.926	11.187**
Computer Attitude	*Between Groups* *Within Groups* *Total*	1 68 69	312.891 5201.980 5514.871	312.891 76.500	4.090*
Geography Attitude	*Between Groups* *Within Groups* *Total*	1 54 55	245.647 11671.210 11916.857	245.647 216.134	1.137
LSI AC-CE	*Between Groups* *Within Groups* *Total*	1 53 54	5.928 6629.453 6635.382	5.928 125.084	0.047
PSI Confidence	*Between Groups* *Within Groups* *Total*	1 53 54	114.808 3227.373 3342.182	114.808 60.894	1.885
PSI Approach/Avoidance	*Between Groups* *Within Groups* *Total*	1 53 54	28.731 4319.014 4347.745	28.731 81.491	0.353
Card Rotation	*Between Groups* *Within Groups* *Total*	1 63 64	197.427 64030.635 64228.062	197.427 1016.359	0.194
Hidden Figures	*Between Groups* *Within Groups* *Total*	1 57 58	1713.634 182443.89 184157.53	1713.634 3200.770	0.535
Vandenberg Mental Rotation	*Between Groups* *Within Groups* *Total*	1 61 62	813.740 15515.244 16328.984	813.740 254.348	3.199

*$p<.05$ ** $p<.01$

Table 4-6. *ANOVA Results on Pretests for Race.*

Cognitive Measure		*df*	***Sum of squares***	***Mean of squares***	***F***
Computer Use	*Between Groups* *Within Groups* *Total*	2 67 69	312.314 11243.172 11555.486	156.157 167.809	0.931
Computer Attitude	*Between Groups* *Within Groups* *Total*	2 67 69	435.953 5078.918 5514.871	217.977 75.805	2.876
Geography Attitude	*Between Groups* *Within Groups* *Total*	2 53 55	1258.986 10657.871 11916.857	629.493 201.092	3.130
LSI AC-CE	*Between Groups* *Within Groups* *Total*	2 52 54	655.738 5979.643 6635.382	327.869 114.993	2.851
PSI Confidence	*Between Groups* *Within Groups* *Total*	2 52 54	240.451 3101.731 3342.182	120.225 59.649	2.016
PSI Approach/Avoidance	*Between Groups* *Within Groups* *Total*	2 52 54	17.970 4329.776 4347.745	8.985 83.265	0.108
Card Rotation	*Between Groups* *Within Groups* *Total*	2 62 64	4246.152 59981.909 64228.062	2123.076 967.450	2.195
Hidden Figures	*Between Groups* *Within Groups* *Total*	2 56 58	4153.430 180004.10 184157.53	2076.715 3214.359	0.646
Vandenberg Mental Rotation	*Between Groups* *Within Groups* *Total*	2 60 62	707.337 15621.647 16328.984	353.669 260.361	1.358

Table 4-7. *ANOVA Results on Pretests for Class.*

Cognitive Measure		*df*	***Sum of squares***	***Mean of squares***	*F*
Computer Use	*Between Groups* *Within Groups* *Total*	2 67 69	62.828 11492.658 11555.486	31.414 171.532	0.183
Computer Attitude	*Between Groups* *Within Groups* *Total*	2 67 69	68.168 5446.703 5514.871	34.084 81.294	0.419
Geography Attitude	*Between Groups* *Within Groups* *Total*	2 53 55	195.329 11721.528 11916.857	97.664 221.161	1.442
LSI AC-CE	*Between Groups* *Within Groups* *Total*	2 52 54	103.807 6531.575 6635.382	51.903 125.607	0.413
PSI Confidence	*Between Groups* *Within Groups* *Total*	2 52 54	16.461 3325.721 3342.180	8.231 63.956	0.129
PSI Approach/Avoidance	*Between Groups* *Within Groups* *Total*	2 52 54	217.159 4130.586 4347.745	108.580 79.434	1.367
Card Rotation	*Between Groups* *Within Groups* *Total*	2 62 64	210.817 64017.244 64228.062	105.409 1032.536	0.102
Hidden Figures	*Between Groups* *Within Groups* *Total*	2 56 58	630.751 183526.77 184157.53	315.376 3277.264	0.096
Vandenberg Mental Rotation	*Between Groups* *Within Groups* *Total*	2 60 62	174.852 16154.132 16328.984	87.426 269.236	0.325

Table 4-8. *ANOVA Results on Pretests for Major.*

Cognitive Measure		*df*	***Sum of squares***	***Mean of squares***	***F***
Computer Use	*Between Groups* *Within Groups* *Total*	4 65 69	844.671 10710.815 11555.486	211.168 164.782	1.281
Computer Attitude	*Between Groups* *Within Groups* *Total*	4 65 69	236.762 5278.109 5514.871	59.161 81.202	0.729
Geography Attitude	*Between Groups* *Within Groups* *Total*	4 51 55	2361.065 9555.792 11916.857	590.266 187.368	3.150*
LSI AC-CE	*Between Groups* *Within Groups* *Total*	4 50 54	299.445 6335.936 6635.382	74.861 126.719	0.591
PSI Confidence	*Between Groups* *Within Groups* *Total*	4 50 54	250.501 3091.681 3342.182	62.625 61.834	1.013
PSI Approach/Avoidance	*Between Groups* *Within Groups* *Total*	4 50 54	90.865 4256.881 4347.745	22.716 85.138	0.267
Card Rotation	*Between Groups* *Within Groups* *Total*	4 60 64	4901.453 59326.609 64228.062	1225.363 988.777	1.230
Hidden Figures	*Between Groups* *Within Groups* *Total*	4 54 58	22653.750 161503.78 184157.53	5663.437 2990.811	1.894
Vandenberg Mental Rotation	*Between Groups* *Within Groups* *Total*	4 58 62	129.630 16199.354 16328.984	32.407 279.299	0.116

*$p<.05$

The null hypothesis for this portion of the research stated that the correlation between the participants' scores on these tests and their success in the class would not be significant. The alternate hypothesis states that the correlations would be significant and positive. Correlation was determined by calculating a Pearson-*r* coefficient of linear correlation between the students' success in the class and the cognitive and demographic variables previously described. Student success was based on their final grade as well as performance on lecture exams, lab exercises, and a project. The results of these correlations are summarized in Table 4-9. There was a failure to reject the null hypothesis for all of the correlations between the cognitive measures and the students' grades except for project grade and the Geography Attitude Measure (r=0.395) and project grade and the Concrete to Abstract scale of the Learning Style Inventory (r=0.274). These correlations indicate that participants who are more successful on their project have a more favorable attitude toward geography and a learning style that involves more abstract thinking.

The second aspect of this study examines the cognitive measures as predictors of the students' success in the GIS course. The low correlations as shown in Table 4-9, suggests there are no single measures that can predict success in the class. Based on these correlations, the students' success on projects could be predicted but not the other aspects of their success.

Because none of the cognitive measures can act as a single, strong predictor of student performance success, the relationship between student success and the effect of these independent variables in combination was also examined. A forward, stepwise

Table 4-9. Correlation Matrix of Grades and Cognitive Measures.

	n	Final Grade	Lecture Grade	Lab Grade	Project Grade
Final Grade	70	1			
Lecture Grade	70	0.884**	1		
Lab Grade	70	0.723**	0.369**	1	
Project Grade	70	0.281*	0.187	0.119	1
Computer Use	70	0.191	0.211	0.091	0.118
Computer Attitude	70	0.169	0.220	0.063	-0.009
Geography Attitude	56	0.097	0.188	-0.097	0.395**
LSI AC-CE	54	-0.028	-0.024	-0.097	0.274*
PSI Confidence	54	0.024	0.071	-0.054	0.171
PSI Approach/Avoidance	54	0.254	0.217	0.178	0.140
Card Rotation	65	-0.034	0.046	-0.162	0.203
Hidden Figures	59	-0.055	0.002	-0.150	0.144
Vandenberg Mental Rotation	63	-0.181	-0.108	-0.228	0.154

*$p<0.05$ **$p<0.01$

multiple regression was calculated for each of the measures of success. This type of analysis begins by calculating the regression with the criterion variable that explains the greatest amount of variance in the dependent variable. Each subsequent step adds the one criterion variable that increases explained variance the most. The steps continue until all possible variables have been added (Diekhoff 1992). The criterion variables for this analysis are the scores on each of the cognitive measures; the dependent variables are the measures of success. The results of the regression analyses are summarized in Tables 4-10, 4-11, 4-12, and 4-13 for the dependent variables of final grade, lecture grade, lab grade, and project grade respectively.

Table 4-10. *Forward, Step-Wise Multiple Regression with Final Grade as the Dependent Variable*

Step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
R^2	0.070	0.119	0.130	0.142	0.151	0.161	0.173	0.180	0.184
Constant	94.846	81.206	75.093	68.371	67.217	68.965	70.508	70.205	69.783
Cognitive Measure									
Approach/Avoidance	0.247	0.236	0.223	0.254	0.261	0.281	0.268	0.280	0.274
Computer Use & Experience		0.159	0.159	0.186	0.196	0.009	0.009	0.006	0.006
Geography Attitude			0.006	0.009	0.009	0.010	0.010	0.010	0.115
Confidence				-0.140	-0.141	-0.158	-0.151	-0.150	-0.157
LSI AC-CE					0.007	0.009	0.009	0.008	0.008
Computer Attitude						0.180	0.213	0.227	0.251
Vandenberg Mental Rotation							-0.666	-0.009	-0.008
Card Rotation								0.003	0.002
Hidden Figures									-0.001

Table 4-11. *Forward, Step-Wise Multiple Regression with Lecture Grade as the Dependent Variable*

Step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
R^2	0.044	0.088	0.105	0.113	0.130	0.141	0.148	0.154	0.159
Constant	63.199	77.370	64.852	66.197	62.525	72.067	71.927	64.210	63.231
Cognitive Measure									
Computer Attitude	0.341	0.359	0.364	0.397	0.373	0.634	0.683	0.715	0.746
Approach/Avoidance		0.319	0.292	0.275	0.301	0.333	0.315	0.355	0.362
Geography Attitude			0.126	0.126	0.132	0.137	0.170	0.204	0.209
Vandenberg Mental Rotation				-0.009	-0.135	-0.148	-0.139	-0.135	-0.134
Card Rotation					0.006	0.007	0.007	0.007	0.007
Computer Use & Experience						-0.229	-0.239	-0.224	-0.226
Hidden Figures							-0.002	-0.002	-0.002
Confidence								-0.168	-0.173
LSI AC-CE									0.010

Table 4-12. *Forward, Step-Wise Multiple Regression with Lab Grade as the Dependent Variable*

Step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
R^2	0.070	0.127	0.166	0.184	0.188	0.192	0.194	0.195	0.195
Constant	65.979	80.909	82.761	76.305	76.667	74.361	69.145	68.858	68.740
Cognitive Measure									
Computer Use & Experience	0.257	0.245	0.276	0.316*	0.330*	0.420	0.419	0.417	0.417
Approach/Avoidance		0.300	0.264	0.321	0.310	0.294	0.294	0.290	0.291
Vandenberg Mental Rotation			-0.157	-0.151	-0.132	-0.122	-0.122	-0.119	-0.119
Confidence				-0.212	-0.216	-0.207	-0.240	-0.245	-0.246
Card Rotation					-0.003	-0.003	-0.003	-0.003	-0.003
Computer Attitude						-0.155	-0.144	-0.127	-0.123
Geography Attitude							0.004	0.006	0.006
Hidden Figures								-0.007	-0.007
LSI AC-CE									0.001

*$p < .05$

Table 4-13. *Forward, Step-Wise Multiple Regression with Project Grade as the Dependent Variable*

Step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
R^2	0.184**	0.297**†	0.373**†	0.393**	0.415**	0.421**	0.458**	0.459**	0.459**
Constant	49.851	45.994	30.731	41.531	39.720	32.241	23.753	22.935	22.989
Cognitive Measure									
Geography Attitude	0.423**	0.441**	0.457**	0.440**	0.438**	0.437**	0.427**	0.430**	0.428**
LSI AC-CE		0.433*	0.386*	0.395*	0.401*	0.419*	0.385*	0.385*	0.385*
Card Rotation			0.123*	0.134*	0.106	0.010	0.009	0.009	0.009
Approach/Avoidance				0.226	0.242	0.230	0.179	0.184	0.184
Vandenberg Mental Rotation					0.153	0.148	0.187	0.187	0.187
Computer Use & Experience						0.010	0.443	0.444	0.445
Computer Attitude							-0.587	-0.584	-0.587
Confidence								-0.002	-0.002
Hidden Figures									0.001

**p*<0.05 ***p*<0.01 †Change in R^2 is significant (p<0.05)

The multiple regression analysis revealed that only 18.4 percent of variance (R^2) in the final grade and 15.9 percent of the variance in the lecture grade respectively could be explained by the independent measures (see Table 4-10 and 4-11 on pages 79 and 80 respectively). For these two regression models, there are no significant values of R^2, no significant changes in R^2 for each step, and no significant regression coefficients (*b* values).

The regression model for the lab grade is only slightly better (see Table 4-12 on page 81). This model explains 19.5 percent of the lab grade and there are no significant values of R^2, no significant changes in R^2 for each step. However, steps 4 and 5 of this model contain a positive, significant regression coefficient for the measure of computer use and experience.

If three of the independent variables from the fourth step of Table 4-12 are held constant, then the effect of an increase by one point on the fourth variable can be determined. For example, if the independent variables of Approach/Avoidance, Vandenberg Mental Rotation, and Confidence are held constant, and the score on the Computer Use and Experience increases by one point, then the predicted value for the lab grade increases by 0.316.

A much stronger relationship is found between the independent variables and the dependent variable of the project grade (see Table 4-13). This multiple regression model explains 45.9 percent of variance in the project grade. In this model, R^2 is significant at each step and the change in R^2 is significant from step 1 to step 2 and from step 2 to step 3. The regression coefficients for the first two independent variables, Geography

Attitude and LSI AC-CE, are significant for each step of the model. The third independent variable, Card Rotation, is significant for the first two steps after it has been added to the model.

Summary

In general there is a failure to reject the null hypotheses for this study. There was only a limited amount of improvement in the scores of the cognitive tests as a result of taking the GIS class; there was very little discrimination among the sub-populations, and the cognitive measures provide little in the way of predicting a participant's final grade.

Analysis of GIS Instruction at Other Universities

In order to increase the application of this study, the class structure and organization of the classes taught at Texas A&M University were compared to syllabi obtained from other universities. On-line syllabi were located through the Higher Education Directory at the Yahoo internet portal (http://dir.yahoo.com/Education/Higher_Education/Colleges_and_Universities/By_Region/U_S_States) and the ESRI online database of academic GIS programs (http://gis.esri.com/university/onlinedb.cfm). In addition, a set of criteria was developed to guide the syllabi selection process:

1) Only courses from institutions operating on a semester system were utilized,
2) Only GIS classes that were identified as introductory were included, and
3) Only GIS classes that were taught in a geography, geology, or geoscience department were included.

In addition to the syllabi, the course description from each university's on-line catalog was collected. Together the on-line documents were examined for the following content:

1) Prerequisites,
2) Credit hours and length of meeting times for lectures and labs,
3) Required texts,
4) Primary and secondary software,
5) Grading criteria,
6) Major topics and the percent of time allocated to the instruction of those topics.

Syllabi were collected from 38 different universities during the 2000-2001 academic year. According to *Perterson's Guide to Four-Year Colleges* (Thompson Corp. 2004), enrollment of universities in this survey ranged from 2,691 at the University of Tulsa to as many as 36,802 at the University of Arizona, Tempe. However, with an enrollment that exceeds 45,000 students, Texas A&M University is larger than any of the institutions surveyed. These universities ranged in focus from teaching to research. This is characterized by a range in Carnegie classifications of MA II to Research I (Chronicle of Higher Education 2004). Texas A&M University has a Research I Carnegie classification. Table 4-14 alphabetically lists the universities that were utilized in this study.

Prerequisites

The number and type of prerequisites were determined from the course descriptions found in university catalogs. There were nine universities that did not state a specific prerequisite, although two of these recommended prior computer experience and one recommended taking any class in geography before entering the GIS class. Four recommended classification as a sophomore or higher, and one suggested generic computer experience. Twenty-five universities required the student take a class prior to enrolling in the GIS class. Of these, sixteen required one class, four required two classes, and five required three classes. Seventeen universities required classes from the geoscience department only, two required computer classes only, and six required a class from both the geoscience and computer science departments. Of the 39 possible prerequisite classes, the most frequent requirement, made by eighteen universities, is a class in cartography or spatial analysis. The second most frequently listed prerequisite, made by eight universities, is a tie between classes in introductory geographic techniques/methods and classes offered in computer science. Two universities required a general or introductory geoscience class, one required a remote sensing class, and two required a geoscience class but did not specify a particular class.

The prerequisite for Texas A&M University is that the student be classified as a junior or senior.

Table 4-14. Universities with Syllabi Reviewed

College/University	Credit Hours	Lecture time	Lab time
Arizona State University	3	1:40	2:00
California State, Long Beach	3	1:40	1:50
California State, Fullerton	3	1:45	1:00
California State, Northridge	4	1:40	6:00
Central Michigan University	3	3:40	--
Florida State University	3	2:30	--
George Washington University	3	2:30	--
Illinois State University	3	--	--
Kansas State University	3	1:40	1:50
Mary Washington College	4	2:30	1:50
Miami University, Ohio	3	1:40	1:50
Michigan State University	3	1:40	1:50
Middle Tennessee University	4	2:45	2:45
Millersville University	3	1:40	1:50
NE Oklahoma University	3	2:30	--
Northern Illinois University	3	2:30	1:50
Rutgers University	3	2:50	--
Sam Houston State University	3	2:00	2:00
San Diego State University	3	1:40	2:40
Slippery Rock University	3	--	--
Southern Connecticut State University.	3	2:30	--
University of Alaska, Anchorage	4	1:50	1:50
University of Alaska, Fairbanks	3	2:30	3:00
University of Colorado, Boulder	4	2:40	3:00
University of Connecticut	4	2:00	4:00
University of Georgia	3	2:30	3:55
University of Hawaii, Manoa	3	2:30	--
University of Idaho	3	2:30	1:50
University of Michigan	4	3:00	2:00
University of New Orleans	3	2:30	--
University of North Dakota	3	2:30	--
University of North Florida	3	2:30	--
University of Oklahoma	3	2:30	--
University of Tulsa	3	2:30	2:50
University of West Florida	4	2:30	2:00
University of Wisconsin, Eau Claire	3	1:40	1:50
University of Wisconsin, Stephens Point	3	1:40	1:50
Valdosta State University	3	1:40	1:50

Credit Hours and Length of Meeting Times for Lectures and Labs

Thirty-one institutions listed their introductory GIS class as a 3-credit-hour class and eight listed it as a 4-credit-hour class (see Table 4-16). All of the four-credit-hour institutions had separate meeting times for lectures and labs, but that did not mean they met for a longer total time span. Twenty of the three-credit-hour institutions also had a separate lab. The remaining 11 did not schedule a formal time for lab meetings; rather, a portion of lecture time each week was devoted to hands-on software instruction. Regardless of the length of time established for lecture and lab meetings, the syllabi often stated that students must devote time outside of class to learn how to operate the software.

Because there was no noticeable difference in the length of time spent in the lectures and labs with regard to the number of credit hours, the length of time spent in the lectures and labs was much more informative than the number of credit hours. This information, however, was provided by only 25 of the 39 syllabi. For the purpose of this analysis, an hour of class time is defined as 50 to 60 minutes. The lecture portion for 14 classes met for the equivalent of two hours and 11 met for the equivalent of three hours. Nineteen of the classes had labs that met for a two-hour session, four that met for a three-hour session, one met for a four-hour session, and one met for a six-hour session.

Texas A&M University lists its class as three credit hours. Lectures meet for the equivalent of three hours and the labs meet for the equivalent of two hours.

Required Texts

Most of the syllabi required the students to purchase one or more textbooks. However, a book was not always mandatory as some syllabi listed the textbook as recommended or optional, and a few did not list a textbook at all. When no textbooks were listed, there were some professors who did not list any readings while others provided readings that the student could find in the reserve area of the library or with the department secretary. Alternatively, the student might be required to purchase a packet of readings, or the professor might post readings on the Internet. Table 4-15 lists the books in order of popularity and does not distinguish between required and optional readings. Both professors at Texas A&M University required *Fundamentals of Geographic Information Systems* by Michael DeMers for theoretical material and *Getting to Know ArcView* by ESRI for laboratory reference. In addition, Dr. Liu also required *Understanding GIS the ArcInfo Method* by David Rhind and Teresa Connolly for use in the lab.

Primary and Secondary Software

All of the syllabi listed at least one GIS software package that would be utilized during the class. Market dominance by the ESRI products, ArcView and ArcInfo, was evident. Twenty-nine listed ArcView and four listed ArcInfo as the primary software with which students would work. IDRISI was mentioned twice while GeoMedia and MapInfo were each listed once. Two syllabi did not list a primary software package; instead multiple programs were listed. Nine syllabi also mentioned the use of a secondary software package. Five identified ArcInfo, three identified IDRISI, and one

Table 4-15. Frequency of Required Textbooks.

Title	Author(s)	Publisher	Yr. Published	Freq.
Getting to Know ArcView	ESRI	ESRI; Press Redlands, CA	1996, 1997, 1998	17
Getting Started with Geographic Information Systems	Clarke	Prentice Hall; Upper Saddle River, NJ	1999, 2001	12
Fundamentals of Geographic Information Systems	DeMers	John Wiley and Sons, Inc.; New York, NY	1997, 2000	10
An Introduction to Geographical Information Systems	Heywood, Cornelius, and Carver	Prentice Hall; Upper Saddle River, NJ	1998	6
Geographic Information Systems: An Introduction	Star and Estes	Prentice Hall; Engelwood Cliffs, NJ	1990	3
Understanding GIS the ArcInfo Method	Rhind and Connolly	John Wiley and Sons, Inc.; New York, NY	1998	3
Geographic Information Systems: An Introduction	Bernhardson	John Wiley and Sons, Inc.; New York, NY	1999	2
Inside ArcView GIS	Hutchinson and Daniel	OnWorld Press; Albany, NY	1997, 2000	2
Geographic Information Systems: A Management Perspective	Aranoff	WDL Publications; Ottowa, Canada	1989, 1993	1
ESRI Guide to GIS Analysis	Mitchell	ESRI; Press Redlands, CA	1999	1
Extending ArcView GIS	Ormsby, and Alvi	ESRI; Press Redlands, CA	1999	1
Map Use Reading, Analysis, and Interpretation	Muehrcke and Muehrck	JP Publications; Madison WI	1998	1
Elements of Cartography	Robninson et. al.	John Wiley and Sons, Inc.; New York, NY	1995	1
GIS concepts and ArcView Methods	Theobald	Natural Resource Ecology Laboratory; Ft Collins, CO	2000	1

identified GRASS as the secondary package. Professors at Texas A&M University identified ArcView as the primary software with ArcInfo as the secondary software.

Grading Criteria

Thirty-eight of the syllabi listed the grading criteria and only one did not. The way in which students were evaluated in these classes varied considerably. As one would expect, final grades were based on a combination of various criteria: tests, quizzes, lab experiences, projects, out of class assignments/readings, and attendance. There was also a great deal of variation in the weight placed on each of these criteria as well as the number or frequency of these various forms of evaluation.

All but three syllabi used a combination of examinations and lab exercises as part of the overall grade. Of these three, one syllabus identified examinations as the only means of evaluation, and two did not use exams at all but based their grades on lab exercises and a project. Seven syllabi used a combination of exams and labs, 18 used a combination of three criteria, and 12 used a combination of four criteria. The most frequently used set of criteria, found on eleven syllabi, was the combination of exams, labs, and projects.

The grading criteria used by the professors at Texas A&M University fell within the mode of the national sample—the three criteria of exams, labs, and project. Table 4-16 shows the comparison of the percentages used by the Texas A&M University professors and the national average for the three criteria. Note that these professors' criteria fall within one standard deviation of the national average.

Table 4-16. Comparison of Grading Criteria

	Exams	Labs	Projects
Avg. (std. dev.)	47.01 (17.24)	32.82 (14.39)	23.82 (7.32)
Liu	45	40	15
Klein	40	30	30

Major Topics and the Percent of Time Allocated to the Instruction of Those Topics

Of the 39 syllabi, 30 provided a general outline for the course. The number of topics addressed, the length of time dedicated to each topic, and the sequence of these topics varied from syllabus to syllabus. There is a wide range of methods by which the topics of GIS were addressed in these syllabi. Analyzing the syllabi for topics discussed in the classes was accomplished by systematically and repeatedly reviewing those syllabi, developing a system of codes, and then categorizing topics from the syllabi into the coded categories. These coded categories and the average length of time, the lower and upper quartiles for length of time, and the amount of time allocated to these topics by the Texas A&M University professors are listed in Table 4-17.

If the amount of time allocated by the Texas A&M University professors fell within the second and third quartiles (inner quartile range), the length of time was considered typical. If it fell outside of the inner quartiles range, the length of time was considered to be an outlier for this sample and not typical. Professor Liu was within the inner quartile range on all but four categories and Professor Klein fell within the inner quartile range on all but three categories. In each of these categories Professor Klein allocated a greater amount of time on those topics. Professor Liu allocated a greater length of time for three categories but a shorter length of time for one category.

Table 4-17. *Time Allocation to Major Topics.*

Major Topical Areas	Avg. Percent of Time	Range of time	Q1	Q3	TAMU Liu	TAMU Klein
Introduction/Overview of GIS	6.4	18.3	3.4	7.1	3.4	3.6
GIS and cartography	8.4	33.3	3.4	11.7	3.4	10.7
Overview of spatial (geographic) data	6.2	23.3	0.0	8.9	3.4	0.0
Data structures	9.0	23.1	6.6	12.8	13.8	7.1
Data maintenance	16.1	35.7	9.5	22.1	6.9	25
Spatial data analysis and operations	17.6	37.2	11.4	26.9	31.0	28.6
GIS output, map design, and visualization	2.9	12.5	0.0	6.1	10.3	10.7
Other geospatial technologies	1.7	10.3	0.0	3.4	0.0	0.0
Case studies, applications, and real world examples	10.3	41.4	0.0	13.9	13.8	0.0
Software instruction or demonstration	5.0	35.3	0.0	7.3	0.0	0.0
Class organization	11.5	26.7	7.1	15.7	10.3	14.3
Lab work	2.1	42.9	0.0	0.0	0.0	0.0
Student presentations	2.8	13.8	0.0	4.3	3.4	0.0

Summary

A wide range of syllabi and course descriptions were collected from the Internet. Analysis of this national sample of syllabi revealed that even though there is a great deal of individual variation among GIS classes, there are similarities that emerge with regard to structure and content. With only a few exceptions, the structure and content of the GIS classes taught by the professors at Texas A&M University fell within the averages of the syllabi sampled.

CHAPTER V

DISCUSSION AND CONCLUSIONS

The first part of this chapter provides an interpretation of the results for each of the research objectives analyzed in Chapter Four. The second part of this chapter describes conclusions based on the significant findings of this research. This is followed by a set of recommendations for GIS instructors. The final section of this chapter offers suggestions for future research.

This study has two principle objectives: 1) to investigate the cognitive skills and abilities of students enrolled in an introductory university course of GIS and 2) to determine if there is a significant relationship between the cognitive factors and the students' success in the class. The relationships among these research objectives, independent measures, dependent measures, and the operational research questions are represented in Figure 1.

Discussion of Pre-test and Post-test of Cognitive Factors

The first hypothesis was concerned exclusively with the students' scores on cognitive tests. The research questions related to this hypothesis asked if there was a change in these scores as a result of being enrolled in, and finishing, an introductory GIS class and if these scores were different among the different sub-populations in the class. Results from this analysis showed a statistically significant increase in the scores on four of the tests. The first of these is the computer understanding and experience scale. This a self-report measure that assesses basic computer skills; higher scores indicate better skill at using a computer. The second is the card rotation test. This is a timed test that requires subject to mentally rotatte two-dimensional objects; higher scores indicate greater spatial ability. The third test on which participants scored significantly higher on the post-test was the hidden figures test. This is a timed test, the objective of which is to identify a figure that is hidden in a geometric pattern. A higher score indicates greater spatial ability. The fourth test is the Vandenberg mental rotations test. This is a timed test requiring mental rotation of three-dimensional objects; higher scores indicate greater spatial ability.

Computer Abilities

Because much of the work for GIS is done on computer, it was not a surprise that there was an increase in the participants' computer abilities as measured the computer use and experience test. GIS requires that the user manipulate and manage an extensive amount of data. Lab exercises conducted by the participants forced them to expand their computer skills beyond those required to operate Microsoft Office products or other simple software. Anecdotal discussions with the participants also indicated that the extent to which they were required to work with computers was a source of frustration for them. Students became frustrated over things such as glitches in their Windows network accounts and basic file management procedures such as locating shared folders on network drives, copying, moving, opening, saving, or deleting files or folders. Some of the participants complained that there was an assumed level of computer skill that was higher than they possessed at the beginning of the semester. There was also frustration about getting the software to do what was required for their exercises. This frustration included such things as formatting and editing the data, finding and implementing the appropriate commands with the relevant data layer, or tweaking a layout to get it to look just right. Furthermore, the participants found it very annoying when a mistake with the software, meant they would have to go back to the beginning of the exercise and start over. Frustration with these matters could explain the decrease, although not a statistically significant decrease, in the scores of the measure that reflected their attitude about computers.

A similar source of frustration for the students was a lack of software demonstrations. GIS is a class about a computer software program, and even though the lab exercises provide a computer training component, it was surprising that the GIS software was used very little in the lecture portion of the class. Many of the students felt they would have developed a better understanding of many of the concepts that were defined and described in the lectures if those concepts were subsequently demonstrated with the software. Neither of the Texas A&M professors allocated any time on the syllabus to software demonstration whereas professors from other universities allocated an average of five percent of class time to software demonstrations (see Table 4-19).

Spatial Abilities

A rejection of the null hypothesis, and thereby acceptance of the alternate hypothesis, does not provide a strong reason for the statistically significant increase in scores of the three spatial ability measures. Two possibilities exist that could, either individually or collectively, explain the increase on these scores.

First, it should be noted that increases in the scores of the spatial abilities tests could be due to the participants becoming test-wise. The administration of the pre-test and post-test was separated by approximately 12 weeks. This was the longest period by which the two tests could be separated given the time constraints of the semester. Although it is unlikely that the participants remembered answers to particular problems, it is possible. It is also likely that they were able to work more quickly on the post-test since they were already familiar with the test procedure. During the administration of the post-test, the participants told the researcher that it was not necessary to work through the practice problems because they remembered the instructions (for consistency they were completed anyway). Therefore the participants required a shorter length of time for familiarization with the type of problems they were trying to solve and could immediately begin completing the task. With few exceptions, the participants completed a greater portion of these timed spatial abilities tests for the post-test than for the pre-test. Assuming accuracy levels at least as high as those on the pre-test, this would lead to higher scores on the spatial abilities tests.

Second, research shows that when allowed to practice performing spatial activities or tasks, participants' scores on paper and pencil tests of spatial ability improve (Vandenberg and Kuse 1978, Colley and Beech 1989, Stumpf 1993, De Lisi and Cammarano 1996, Saccuzzo et. al. 1996, Strohecker 2000). Furthermore, it has been suggested that using a computer can improve scores on spatial abilities tests because many computer applications require spatial abilities (De Lisi and Cammarano 1996, Saccuzzo et. al. 1996). Thus the increase on scores of spatial ability tests could be due to the improvement in the participants' computer abilities. Therefore, when students use GIS, they may be, in fact, practicing the skills measured by spatial ability tests but not necessarily improving their ability to solve the type of spatial problems for which geographers and others often use GIS. For example, a student may become adept at recognizing street patterns and calculating traffic flow values; however, this is not necessarily an indication that the student will be able to determine an appropriate location for a new stop light to regulate traffic flow.

Other Measures

For the remaining measures of learning style, problem solving, and geography attitude, it is not surprising that the scores on these measures did not improve over the course of the semester. The authors and developers of the learning style measure (Smith and Kolb 1996) and the problem solving measure (Heppner 1988) used by this researcher state that these measures are stable over periods of time longer than a single semester, assuming that learning strategies and problem-solving strategies are not specifically taught. In addition, since this class does not try to make changes in these cognitive factors or attitudes toward geography it was not expected that these measures would change significantly during the course of a 15-week semester. Because these measures are stable, they were included principally as part of the corrlational portion of this dissertation.

Scores by Different Sub-Populations

Very few significant differences on the scores of the cognitive tests were found between the student sub-populations based on gender, race, class, and area of study. Given that there were nine different cognitive measures and four different sub-populations, there is a total of 36 different bivariate correlations. Only two of these bivariate relationships had a score that was significant and both of those differences were based on gender.

Differences by Gender

Computer Abilities

On the pretest, there were no significant differences between the two genders except that males scored higher on the computer use and the computer attitude measures. Literature that describes gender differences in computer use and attitudes indicate mixed results. None of the studies cited in the literature review reported that females had more favorable attitudes or experience with computers than males. These studies revealed either there was no significant difference between males and females or that males demonstrate more favorable attitudes and experience toward computers (Bandalos and Benson 1990, Kay 1993, Levine and Donitsa-Schmidt 1997). For this reason, the developers of the computer use and experience scale (Potosky and Bobko 1998) are concerned about generalizing their results to other samples even though they found that males have more computer experience. Findings from the developers of the computer attitude measure (Bandalos and Benson 1990) suggest that males generally have more favorable attitudes toward computers than do females.

Spatial Abilities

It is interesting to note that there was not a gender difference on the spatial abilities tests. A spatial ability gender difference has been disputed in recent times; however, it is still widely accepted that males perform better on rotation tasks then females (Self and Gollege 1994, Montello et. al. 1999). An explanation for this lack of difference might be found in the breakdown of majors by gender: of the 20 females enrolled in the GIS course, 13, or 65 percent, were geography majors. Self and Gollege (1994) cite studies that found females with geographic training produced scores on spatial abilities tests equivalent to, or higher than, the scores of males. Therefore, it seems plausible that the females enrolled in the GIS course would have the necessary geographic training that might eliminate any gender differences on the spatial abilities measures.

Predicting Success Based on Cognitive Test Scores

The hypothesis for this objective was concerned with predicting achievement in the GIS class based on the participants' scores on the cognitive tests. If there is a relationship between these cognitive factors and the grades the participants received for the class, then this could serve as a way to identify students who might have more difficulty with the skills and concepts required to succeed in learning GIS. The alternate hypothesis for this research objective stated that there would be a positive and significant relationship between the scores on the cognitive tests and the students' grades for the course, as well as their grade on the lecture, lab, and project portion of the class.

The results of this analysis showed that there is very little relationship between the factors measured by any of the cognitive tests and the success of the students in the class. There was a failure to reject the null hypothesis on all but two of the 36 bivariate correlations; and even the two correlations that are significant, are only moderate in size (see Table 4-9). The strongest correlation is between the project grade and scores on the geography attitude measure (r=0.395). The relationship between these variables shows that participants with a more favorable attitude toward geography have a greater rate of success in the class. The other significant correlation is between the project grade and LSI AC-CE scale (r= 0.274). Higher values on the LSI AC-CE scale indicate a preferred style of learning that is based on abstract conceptualization. According to the developers of this measure, individuals who prefer this learning style tend to grasp new information by "thinking about, analyzing, or systematically planning rather than using intuition or sensation as a guide" (Smith and Kolb 1996, 11). Therefore, students in the GIS course who demonstrated a more abstract learning style had a greater rate of success.

The weakness of the relationship between the cognitive measures and success in the class is further indicated by multiple regression analyses. Using each of the measures of success, the regression equations for the final grade, lecture grade, and lab grade did not account for as much as 20 percent of the variance in those assessments. However, for regression with project grade as the dependent variable, nearly 46 percent of the variance was explained by the cognitive ability and attitudinal variables. This suggests that the cognitive skills required to achieve success on the project are more closely related to the types of skills measured by the psychometric tests utilized in this research. The project that participants were required to complete is more closely related to the type of GIS activities used in a real-world situation. Therefore, the project grade is more representative of an authentic learning assessment and should be considered the most meaningful measure of achievement. In this regard, the cognitive measures can be used to predict successful learning. Unfortunately the project grade contributed the smallest percentage to the overall grade and thus had the least influence on the students' overall success in the class. This is also apparent on the correlation matrix (see Table 4-9); the project grade had the weakest correlation of any of the success measures with the overall grade (r=0.281) and was not significantly correlated with the lecture grade or lab grade (r=0.187 and r=0.119 respectively).

The fact that the project did not carry a higher percentage of the overall grade created a problem for the participants. They did not deem it as important as exams and lab exercises. As such, the participants were less inclined to work seriously on the project until later in the semester when it was closer to its due date. This created a further complication for many of the students because they had to rush to finish their projects on time and as a result they were not able to develop their project fully or in an appropriate manner. Students who had to rush often attempted several different projects until they found something that could be done quickly and easily. Quite often, this meant that efforts on these projects were devoted merely to creating a map without using any of the software's analytical capabilities. Ultimately, these students would not get the full benefit of learning GIS through the project process.

With the exception of the project grade, it is risky to predict student success based on the results of this research. There are three alternate explanations for this failure to reject the null hypothesis. The first explanation suggests that the cognitive measures used in this research study are not related to skills used for learning GIS in the classroom. Lecture exams were based on material from the lectures and the textbook readings. Doing well on the lecture portion of the grade required attending lectures, taking good notes, reading the textbook, studying and reviewing these materials, deciding what information is relevant to the exam, committing that information to memory, and then reproducing the learned material on exams. Doing well on a project requires proposing a research project, formulating a research question, gathering relevant data, analyzing that data in an appropriate manner, interpreting the results of the analysis, proposing a solution to the problem, and effectively communicating a solution in a written report and oral presentation. Therefore, the cognitive requirements necessary to be successful on these two forms of evaluation is quite different. Success on the lecture portion of the course is measured largely with declarative knowledge, that is, factual knowledge about GIS. On the other hand, successful completion of a real-world GIS project is measured more with creativity and conditional knowledge, that is, knowing how, when, or in what condition to apply GIS knowledge..

Comments from students reflected their understanding that the way they learned the conceptual material for the lectures was different than the way they learned the software principles in the lab exercises. Participants perceived the lecture material to be very straightforward. With regard to lecture material, students summarized their feelings with comments like: "I think it's a lot easier to learn textbook kind of stuff." "I just basically memorized… it was just reading the [PowerPoint] slides and notes" or as another stated succinctly, "You learn it, you memorize it, you spit it out on the test." In contrast, students described learning in the labs as characterized by "doing it." They perceived it as "hands-on." One participant explained that labs were more important because "you have to actually use the computer…[and when] you use the computer, you see how [the software] works."

Because of the differences in what took place in lectures as compared to what took place in the labs, many of the students had a hard time bridging the gap between two situations in which they were learning about GIS. Frequently, the subject-matter in the labs was covered at least a week after it was discussed in the lectures. Many of the students expressed confusion about this lack of connection between lecture and lab. Students complained that the lecture made no reference to what would be taking place in the lab and the labs did not make a connection back to what took place in the lecture. Furthermore, some of the subject matter covered in the lecture (i.e., historical roots of GIS) did not pertain at all to learning the software, and students placed very little value on those subjects.

In addition, the difference between learning lecture material versus learning how to use the software in the lab presented a dilemma for the participants. They intuitively understood that working through the labs and understanding the procedure to solve a lab exercise was a better way to learn than by memorizing lecture material. Some students even expressed dissatisfaction with the structure of the labs because they were written in a cookbook style. This meant that by simply following the list of directions given on the exercise sheet, the participant could produce the correct answer to the GIS problem. Many of the students verbalized their desire to do more with the software than merely follow a list of commands on a page. However, because there was no obvious benefit to their grade and a sense of accomplishment was the only reward for taking the time to explore the software more deeply, very few students were willing to put forth that effort. Nevertheless, students' statements were somewhat inconsistent; even though they often stated that they wanted a deeper understanding of the software, they used their time in the lab to work as quickly and efficiently as possible in order to complete the exercise, turn in their work, and leave the lab as soon as possible.

There is another issue related to the argument that the cognitive measures used in this study are not related to learning GIS. Since the measurement of the cognitive factors used for this research are determined from paper and pencil tests, it is uncertain if they can account for the full range of cognitive skills utilized in learning GIS. It has also been suggested that it is unclear as to how scores on such psychometric tests relate to skills and abilities that are called upon in real-word, problem-solving situations (Montello et. al. 1999). Interactions with the students supported this belief. The participants felt that computer skills were vital to succeeding in the class. Even though a few of the participants vaguely alluded to spatial skills and problem-solving skills, most did not believe that the constructs measured by the other survey instruments were related to learning GIS. Therefore, how well one does on one of these cognitive measures may not translate into success in a GIS classroom. In other words, a participant may do well on the cognitive tests but poorly in the class or one may do poorly on the cognitive tests but be successful at learning GIS.

The second explanation for the poor relationship between the cognitive factors and student success in the class suggests that the way(s) by which the professors measured student success is not representative of successful learning of GIS skills. Based on results from the national sample of syllabi of GIS classes, the methods of student evaluation used by the professors in this research are used widely by professors of GIS elsewhere. Therefore unless the majority of GIS professors are evaluating student learning in an inappropriate manner, this explanation does not seem likely to account for the weak correlation between the cognitive factors and student success.

A third possibility is that there are other factors, besides those measured in this research, that contribute to student success in GIS courses. One hypothesis of this type is that good students do well in most, if not all, of their classes. This hypothesis can be tested by correlating students' overall grade point averages (GPA) with their success in the GIS class. This alternate hypothesis would state that there is a significant and positive relationship between success in the GIS class and GPA. A correlation between GPA and each measure of success was determined by calculating a Pearson-*r* correlation coefficient. The correlation coefficient was significant ($p<0.01$) and equal to 0.739, 0.728, 0.432, and 0.466 for final grade, lecture grade, lab grade, and project grade respectively. Again, the difference between success in the overall grade and the lecture grade versus the lab grade and project grade is apparent. Cognitive skills for success in lecture examinations are different than those required for operating the software to complete lab exercises and open-ended research projects. Grades in higher education for most courses, are driven by examinations based on lecture material. Students who do well academically (i.e., students with high GPAs) have developed strategies for success on this type of evaluation. Therefore, it is not surprising that students' GPAs were highly correlated with their grades on the lecture portion of the course and with the final grades. Stated another way, students who are successful in all of their college courses are highly likely to be successful in the lecture portion of the GIS class and have a high overall grade as well.

Entering GPA into the multiple regression analysis as a independent variable supports this assertion as well. A forward, step-wise multiple regression procedure has already been utilized to analyze the relationship between the measures of student success and the independent variables measuring cognitive abilities (see Tables 4-10 through 4-13). If GPA is added to the multiple regression procedure, it should increase the percentage of variance explained by the students' grades. A new forward, step-wise multiple regression procedure that included GPA was calculated for each measure of student success. The difference between the values for R^2 from the analysis of success without GPA and with GPA as an independent variable are summarized on Table 5-1.

The R^2 values increased dramatically for the participants' overall grade and lecture grade, increased moderately for the lab grade but did not change at all for the project grade. It should also be noted that GPA is the first variable entered for each of

Table 5-1. Change in the Variance Explained by Multiple Regression

	Final Grade	Lecture Grade	Lab Grade	Project Grade
R^2 without GPA	0.184	0.159	0.195	0.459
R^2 with GPA	0.651	0.710	0.315	0.459
Change in R^2	0.467	0.551	0.120	0.0

the regression procedures except for the project grade where it is the last to enter the equation. The way that the regression equation responds to the inclusion of GPA strongly supports the explanation that student characteristics that lead to success in the lecture portion of the grade is very different than that the characteristics that lead to success in the lab and project portion of the grade.

A second outside factor may be that the successful participants held a different attitude toward learning in general. A closer look at the correlation matrix (see Table 4-9) shows that for each measure of success, an attitude factor is the highest positively-correlated measure. This includes attitudes toward geography, computers, and problem solving (PSI approach/avoidance). For these measures, a higher score indicates a more positive attitude toward that construct. Therefore, students with a more positive attitude get higher grades in the course. It should also be noted that it is likely that positive attitudes toward geography, computers, and problem-solving are influenced by students' success or failure in the past.

A similar examination of the forward multiple regression analyses (Tables 4-10 through 4-13) shows that at least one (and as many as three) of these attitude measures enters the equation during the first three steps of the regression procedure for each measure of student success. That is, scores on these three factors have the largest impact on the explanation of variance in the students' success in the course. Therefore it is likely that a more positive attitude, in a broader sense, held by some students (perhaps indicating previous success) may be a strong contributor to their success in the GIS course.

Summary and Conclusions

For a long time, educators have realized that learning to use GIS in an academic setting is a time consuming, if not intellectually difficult, endeavor for students in an introductory GIS class. Nevertheless, industry continues to emphasize the importance of GIS as a tool for geo-spatial analysis and GIS continues to be a means for new geography graduates to get their foot in the door of potential employers (Gewin 2004). The significance of GIS as a major market force has been widely accepted in the geography community, and the demand for competent users remains at an extremely high level.

However, only a limited understanding of the cognitive processes that these novices utilize in learning to use GIS exists. Several important cognitive factors have been suggested in literature; however, the literature review for this study found only a small number of studies in which experimental research on the effect of these cognitive factors on learning GIS was performed. The vast majority of studies related to the connection between cognition and GIS learning was descriptive and anecdotal.

The first chapter of this dissertation stated that there were two goals for this research: 1) to investigate pre-existing cognitive skill of the participants and to determine if an improvement in these skills was detectable at the end of the semester and 2) to examine the relationship between these spatial and cognitive abilities and the participants' success in completing the GIS class. Nine psychometric tests were used to evaluate the cognitive factors of computer use and experience, computer attitude, geography attitude, approach and avoidance of problem solving, confidence in problem solving, learning style, and spatial abilities. Student success was measured in four areas: lecture grade, lab grade, project grade, and the final course grade. This research was conducted over two semesters, and 70 students participated in at least one aspect of the research. This research used a positivistic, process-product approach to examine the cognitive factors and the relationship between these factors and student success.

The participants' scores on only four of the nine factors measured showed statistically significant improvement at the conclusion of the GIS class. Improvement was found for the measure of computer use and experience and three spatial ability measures. Since the class dealt directly with the aspects of these cognitive factors, it can be concluded that the improvement on these scores is related to the skills utilized for the successful completion of the GIS class.

The results of bivariate correlations showed that these cognitive factors had virtually no relationship with the success of students taking the GIS class. Only two of the factors, geography attitude and learning style, were significantly correlated with the project grade. However, these were at best, moderate correlations. The remainder of the correlations was either weak or negative and none were statistically significant.

Finally, the multiple regression analysis also demonstrated a weak relationship between the cognitive abilities that were measured and the success of the participant with regard to their lecture grade, lab grade, and overall grade. However, the multiple regression analysis did show that the cognitive measures have some predictive ability for the project grade. It is concluded that scores on these tests collectively cannot predict success on structured classroom evaluations that measure learning in the GIS class; but these scores can predict success on an individual project.

Recommendations for GIS Instruction

Findings from this research offer three recommendations for GIS instruction to improve student learning of GIS:

First, strengthen the use of open-ended exercises and projects. Geographers trained in GIS use the software to perform spatial analyses that lead to the solution of spatial problems. Using GIS in this manner requires the development of sophisticated spatial cognitive skills. As such, the emphasis of GIS instruction should be to help novices develop these spatial skills in order to effectively implement GIS for spatial analysis and spatial problem solving. Unfortunately, spatial analysis and spatial problem-solving are difficult to asses on a lecture exam; they are better assessed by open-ended lab projects or independent class projects. Because this makes the project grade the most authentic means of assessment, instructors should place an adequate emphasis on these types of projects that force the students to think about using GIS from a more spatial perspective and less from a database management perspective.

Second, provide a stronger connection between lectures and lab exercises. This could be done in a number of ways. The simplest way is to make verbal references that would bridge the gap between the labs and lectures. A second method would be to structure the labs and lectures so they more closely parallel on another. A third method would be to demonstrate the GIS software during lectures to emphasize particular concepts or principles. The latter would be especially helpful for students because it would not only show the concept but also the procedure utilized to perform the software-related operation.

Finally, ensure that the students develop a baseline set of computer skills. With computers seemingly omnipresent, it is easy for instructors to assume that students who come into their classroom have a high level of computer literacy. Unfortunately, this more likely means that the students have a high level of computer exposure but not necessarily expertise. Taking time to develop basic skills will reduce the students' frustration and the frustration of the instructor.

Suggestions for Future Research

The relationship that exists between the cognitive skills for learning GIS that are utilized in this research should be explored more deeply. Additional data are required for a more complete analysis and understanding of the cognitive skills utilized by novices when learning GIS. There are several paths that future research could follow.

First, since it is unclear how well paper and pencil psychometric tests relate to learning to use GIS, the development and use of a more authentic form of spatial abilities testing could strengthen the connection between spatial cognitive abilities and learning GIS.

Second, since it is unclear if the changes in the participants' spatial ability scores are due to learning to use GIS or due to increasing their experience in using computers, a follow-up of the spatial ability post-tests at several intervals after the semester is over could clarify this issue.

Finally, there is an extensive body of literature describing what to teach in a GIS class. Unfortunately, little is known about how to present that material in such a way as to best accommodate the learner. Qualitative studies that examine how students develop their skill at using GIS or how they utilize the spatial skills in solving GIS spatial problems could greatly inform instructors on how to teach GIS.

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APPENDIX A

INFORMED CONSENT DOCUMENTATION

Informed Consent Documentation

The purpose of this document is to inform me of a research project in which I am being asked to participate. The research study will take place on the College Station campus of Texas A&M University during the fall semester of the year 2000 and will involve approximately 100 participants.

The purpose of this research is to investigate aspects of mental abilities that may influence success of students who are taking an introductory class of geographic information systems (GIS). There are two parts to this study. Part One will investigate the aspects of learning style, problem solving style, spatial skill, computer aptitude & anxiety, and attitudes and beliefs about geography that novice GIS users demonstrate. Part Two of this study will investigate how novices of GIS utilize the intelligence factors listed above as they develop the skills necessary to use GIS. The results of this study could be used to develop better teaching strategies for instructors of GIS, reduce the time necessary to learn principles of GIS, and even improve the user interface of GIS software.

Participation in any part of this study is strictly voluntary and if I choose to participate in one part of the study it is not necessary to participate in the other part. The professor for this class has guaranteed that my decision whether or not to participate will have no affect on my grade in this class. Furthermore, I will not be penalized if I choose not to participate or answer questions that make me uncomfortable. Even after I begin the study, I understand that I am free to withdraw my consent and discontinue participation at anytime.

If I choose to participate, this is what will happen:

Part One:

I will be asked to complete a questionnaire that contains a few general questions about me and my knowledge of GIS. I will also be asked to complete the following surveys:

- The Learning Style Inventory—identifies the ways I learn and how I deal with ideas and day-to-day situations;
- The Problem Solving Inventory—assesses my awareness and evaluates my problem solving abilities and style;
- Hidden Patterns—tests my ability to recognize a pattern hidden in a picture;
- Card Rotation—tests my ability to mentally rotate two-dimensional objects;
- Vandenberg Mental Rotations—tests my ability to mentally rotate three-dimensional objects;
- Computer Understanding and Experience Scale—measures my basic computer skills as well as confidence and anxiety about using computers
- Geographic Attitudes Measure—measures my attitudes toward geography;

Most people are able to complete all of these tests in less than 90 minutes. Some people find that the results of these tests help improve their study skills. If I am interested in knowing my results I can request that information and it will be provided to me at the end of the semester.

For comparison purposes, I will be asked to complete these same surveys at the end of the semester.

Because this study is investigating the relationship between the skills measured by the surveys listed above and success in the class the researcher will compare my final grade in the class with my scores on these surveys.

All of the information obtained from the survey forms as well as my final grade will be kept confidential and in a secure location that is accessible only by the researcher. In order to ensure confidentiality, identification on these research materials will only be by the last five digits of my student identification number. My name will not appear on any of the survey forms or the final grade form that the professor gives to the researcher.

Please initial one blank:

_____I am willing to participate in Part One

_____I am not willing to participate in Part One

Part Two:

While completing independent lab exercises, I may be asked questions regarding the method that I chose to solve a particular problem. Questions asked at this time may include some of the following: Can I verbally explain how I solved the problem? Why did I choose to solve it in that manner? How did I conceptualize the problem before starting to solve it? What steps did I follow to determine the solution? What alternative methods might I use at another time to solve the same problem? The time required to answer these questions will be approximately 10 minutes, and I will not have to participate in this manner more than twice a month.

In order to expedite the analysis of these questions the researcher may record my responses for this part of the study. However, I understand that the researcher will do so only with my written permission as well as verbal permission at the time of the recording. The recorded audio tapes of these interviews will be stored in a secure location that is accessible only by the researcher.

For this part of the study, the researcher cannot guarantee that my responses will be confidential. This is because the interviews will take place in the computer lab where other students who are present may be able to hear my responses and know that I am participating in this part of the study. Furthermore, I understand that my responses to interview questions may be quoted. Should this occur, I understand that my real identity will be concealed through the use of a fictitious name.

Please initial one blank:

_____I am willing to participate in Part Two

_____I am not willing to participate in Part Two

This research study has been reviewed and approved by the Institutional Review Board Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through Dr. Richard E. Miller, IRB Coordinator, Office of Vice President for Research and Associate Provost for Graduate Studies at (979) 845-1811.

I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

I have been given a copy of this consent form.

____

Signature of Participant and Date

____

Signature of Principal Investigator and Date

If I have any questions regarding this research, I can contact Paul Vincent or his academic advisor, Professor Robert Bednarz, at the Department of Geography, 810 Eller O&M Building, Texas A&M University, College Station, TX 77843-3147 or call (979) 845-7141.

Audio Tape Release Form

I voluntarily agree to be audio taped during the dissertation research being conducted by Paul Vincent during this semester

By signing this form, I understand and acknowledge the following statements:

- The tapes will be used only for analysis of my responses to questions related to this research;
- These tapes will be stored in a locked filing cabinet at Paul Vincent's house until December 31, 2001;
- Either before, or on the date of December 31, 2001, the audio tapes will be physically destroyed by cutting and unraveling the tape.

____
Signature of Participant and Date

____
Signature of Principal Investigator and Date

Refusal to be taped

I do not agree to be audio taped during the research being conducted by Paul Vincent. I understand that I may still participate in the study and that there are no negative consequences for refusing to be recorded.

____
Signature of Participant and Date

____
Signature of Principal Investigator and Date

APPENDIX B

DEMOGRAPHIC QUESTIONNAIRE

Student ID Number (last 5 digits ONLY) _________________

Gender (check one)
- ☐ Male
- ☐ Female

Race/Ethnicity (check one)
- ☐ American Indian
- ☐ Asian or Pacific Islander
- ☐ Black, not of Hispanic origin
- ☐ Hispanic
- ☐ White, not of Hispanic origin
- ☐ Other

What is your major? ______________________________

What level are you? ______________________________
(freshman, sophomore, junior, senior, or graduate)

How many geography courses have you taken? _______________
(NOT including this class and other classes you are taking this semester)

How many computer classes have you taken? _______________
(NOT including any classes you are taking this semester)

Have you taken other GIS classes before this class? _______________
(If yes, please list course names and GIS software packages utilized)

Why are you taking this class?

APPENDIX C

COMPUTER APTITUDE AND ANXIETY

Computer Understanding and Experience

For this questionnaire, you are being asked to respond to statements about your knowledge and perception of computers. Usually it is best to respond with your first impression without giving a statement much thought. Please respond to every item.

Read each statement and indicate the extent to which you agree or disagree with that statement using the scale provided. Mark your responses by circling the number to the left of each statement.

1 Strongly Disagree	2 Disagree	3 Neither Agree nor Disagree	4 Agree	5 Strongly Agree

1 2 3 4 5	I can describe and implement basic troubleshooting techniques for computer systems.
1 2 3 4 5	I like working with computers
1 2 3 4 5	I don't understand how some people can spend so much time working with computers and seem to enjoy it.
1 2 3 4 5	I know what an operating system is.
1 2 3 4 5	I am good at using computers.
1 2 3 4 5	I can access the Internet.
1 2 3 4 5	Figuring out computer problems does not appeal to me.
1 2 3 4 5	I know how to install software on a personal computer.
1 2 3 4 5	I can setup a computer system and connect peripheral devices.
1 2 3 4 5	I can convert graphics from one file format to another.
1 2 3 4 5	I can create, copy, move, rename and delete folders.
1 2 3 4 5	Generally, I feel okay about trying a new problem on a computer.
1 2 3 4 5	I know how to open a file from a floppy disk.
1 2 3 4 5	I know a great deal about computers.
1 2 3 4 5	I have lots of self-confidence when it comes to working with computers.
1 2 3 4 5	I regularly use a personal computer for word processing.
1 2 3 4 5	I am able to use e-mail and the Internet to access information for personal and educational purposes.
1 2 3 4 5	The challenge of solving problems with computers does not appeal to me.
1 2 3 4 5	I know what a database is.
1 2 3 4 5	I am able to copy and paste or cut and paste text or graphics within an application and between multiple, open applications.
1 2 3 4 5	I feel comfortable working with a computer.
1 2 3 4 5	I can use terminology related to computers in an appropriate manner.
1 2 3 4 5	I know how to start up and shut down a computer.
1 2 3 4 5	I am not good with computers.
1 2 3 4 5	I can create and maintain backups.
1 2 3 4 5	I get a sinking feeling when trying to use a computer.
1 2 3 4 5	I am able to open and close an application/program.
1 2 3 4 5	I am computer literate.
1 2 3 4 5	I know how to save a file to a specific location on a hard drive.
1 2 3 4 5	Computers do not scare me at all.

APPENDIX D

GEOGRAPHY ATTITUDE MEASURE

GEOGRAPHY ATTITUDE MEASURE

On the next page are 15 pairs of adjectives that could be used to rate how you feel about Geography. Read each statement and indicate the extent to which one word of the adjective pair describes how you feel about geography. Do not try to remember how you checked similar items earlier in the test. Make each item a separate and independent judgement—it is your first impression, the immediate "feelings" about the items that you want to mark. Place an **x** in one, and only one, space between each adjective pair and be sure that you do not omit any.

Example:

To me Geography is:

	Extremely	Moderately	Slightly	Neither	Slightly	Moderately	Extremely	
Fun	___	_x_	___	___	___	___	___	Not Fun
Sad	___	___	___	_x_	___	___	___	Happy

You might find it easier if you answer as though you were completing a sentence:

To me Geography is *moderately* fun.
To me Geography is *neither* happy nor sad.

Go to the next page to continue the Geography Attitude Measure

Student ID Number (last 5 digits ONLY) _________________

To me, Geography is:

	Extremely	Moderately	Slightly	Neither	Slightly	Moderately	Extremely	
Unlikable	___	___	___	___	___	___	___	Likable
Bad	___	___	___	___	___	___	___	Good
Pleasant	___	___	___	___	___	___	___	Unpleasant
Uncomfortable	___	___	___	___	___	___	___	Comfortable
Dull	___	___	___	___	___	___	___	Exciting
Important	___	___	___	___	___	___	___	Unimportant
Boring	___	___	___	___	___	___	___	Interesting
Relevant	___	___	___	___	___	___	___	Irrelevant
Means nothing	___	___	___	___	___	___	___	Means a lot
Appealing	___	___	___	___	___	___	___	Unappealing
Fascinating	___	___	___	___	___	___	___	Mundane
Worthless	___	___	___	___	___	___	___	Valuable
Engaging	___	___	___	___	___	___	___	Uninteresting
Needed	___	___	___	___	___	___	___	Not needed
Useless	___	___	___	___	___	___	___	Useful

VITA

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