ABSTRACT

HAGEVIK, RITA ANNE. The Effects of Online Science Instruction Using Geographic Information Systems to Foster Inquiry Learning of Teachers and Middle School Science Students. (Under the direction of John E. Penick and Hugh A. Devine)

This study investigated the effects of using Geographic Information Systems (GIS) to improve middle school students' and their teachers' understanding of environmental content and GIS in a constructivist classroom. Constructivism provided the theoretical framework with Bonnstetter's inquiry evolution and Swartz's skillful problem solving as the conceptual framework for designing these GIS units and interpreting the results.

Teachers from nine schools in five counties in North Carolina attended a one-week workshop and fall follow-up session, where they learned how to teach the online Mapping Our School Site (www.ncsu.edu/scilink/studysite) and CITYgreen GIS inquiry-based problem-solving units. Two years after the workshop, one science instructor and one media specialist from the workshop taught the six week Mapping Our School Site (MOSS) unit in the fall and one biotechnology elective teacher taught the MOSS unit in the fall and the CITYgreen GIS unit in the spring.

The students in the MOSS experimental group (n=131) and the CITYgreen GIS comparison group (n=33) were compared for differences in understanding of environmental content. Following the teaching of environmental science with GIS, other factors were investigated such as students' spatial abilities, experiences, and learning preferences. Teachers and students completed the online Learning Styles Inventory (LSI), Spatial Experience Survey (SES), and the Purdue Spatial Visualization Test: Rotations (PSVT:R).

Using ANOVAs, a quiz, unit test, analyses, written conclusions and lab reports indicated that the CITYgreen GIS group learned the environmental content better than the MOSS group. The MOSS group better understood how to design experiments and to use GIS to analyze problem questions Both groups improved in problem identification and problem solving, data accuracy, and hypothesis testing.

An ANOVA was used to compare the spatial reasoning score to learning style as reported on the LSI, and factors on the SES such as handedness, academic courses (geometry, shop class, 3-D courses), non-academic activities (toys, computer games), and sports activities. Males scored higher than females on the spatial reasoning test, the more computer games played the higher the score, and the fewer shop classes taken the higher the score.

Earlier research asserts that qualified teachers who are confident in teaching with GIS are key to the success of the curricula. The effectiveness of the MOSS/CITYgreen GIS teacher workshop was also investigated. Results indicated that 75% of the teachers' integrated GIS into classroom instruction two years after the GIS workshop. Even though teaching experience was negatively related to spatial reasoning test scores, implementation of GIS by teachers in the workshop was not influenced by years of teaching experience. The results indicate that GIS can be universally used for classroom instruction.

Using qualitative analyses, the results of the quantitative analysis were further evaluated. This approach indicated that the students learned more than was reported by the unit test. Even though the CITYgreen GIS students learned more environmental

content than the MOSS students, the MOSS students were better able to analyze problem questions using GIS.

The findings of this study indicate that using GIS may aid students in constructing concepts and in promoting understanding of environmental content, problem solving, experimental design and data analysis, and communicating findings to others. Using GIS in classroom instruction may be a way of incorporating more spatial learning in schools.

THE EFFECTS OF ONLINE SCIENCE INSTRUCTION USING GEOGRAPHIC INFORMATION SYSTEMS TO FOSTER INQUIRY LEARNING OF TEACHERS AND MIDDLE SCHOOL SCIENCE STUDENTS

by
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APPROVED BY:

Chair of Advisory Committee

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DEDICATION

This dissertation is dedicated to my parents

Martha and Dominick Zaccone

who dared me to create broad new thoughts and
challenged me to continue to change and invent

BIOGRAPHY

Rita Anne Hagevik was born in Chicago, IL on August 4, 1956, the daughter of Martha Maria Zaccone and Dominick Charles Zaccone. After graduating from Hinsdale South High School, Clarendon Hills, IL, in June 1974, she entered North Central College in Naperville, IL, later graduating from Meredith College, NC, in May 1989 with a Bachelor of Science in Biology, teaching license grades K-9, science. Rita Hagevik taught middle school science for ten years. In the fall of 1996, she began her graduate work at North Carolina State University, receiving a Masters of Science in Science Education, teaching license grades 9-12 in May 1999. Rita Hagevik entered the Ph.D. program at North Carolina State University in Science Education and Forestry in 1999, where her research efforts have focused on Geographic Information Systems (GIS), spatial cognition and mapping, urban forestry, the teaching of thinking, and appropriate uses of new technologies in schools.

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Rita's hobbies primarily are associated with outdoor activities such as backpacking, canoeing, swimming, and skiing. She loves to travel and wherever she goes enjoys long hikes with many stops as she observes the wonder and beauty of the natural world. Rita Hagevik lives in Wendell, North Carolina with her husband, Bob, and their dog Gypsy.

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I especially want to thank my husband Bob and my children, Sarah and Cheryl, for their unselfish love, support, patience, and understanding. I also acknowledge and thank God for His many blessings. His presence continues to be a source of comfort and strength to me throughout my life's journey.

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CHAPTER ONE. SCIENCE EDUCATION REFORM

Since the publication of the *National Science Education Standards* (National Research Council, 1996), efforts to reform science education in the United States have become a priority. Individuals and groups involved in the development of the *Standards* include the councils of the National Academy of Sciences, The National Academy of Engineering, and the Institute of Medicine as well as teachers, informal educators, politicians, parents, school administrators, curriculum specialists and businesspersons. This group has proposed a vision of science education that emphasizes a new way of teaching and learning about science that reflects how science itself is done. Central to this new vision is inquiry as a way of achieving knowledge and understanding the world. Coupled with this goal, rapid technological advances have further fueled significant changes in thinking about schools and the curriculum.

In addition, behaviorist theories have given way to a constructivist approach to learning in which the learner constructs knowledge from their own perceptions, experiments, experiences, understandings, and inquiries. This agrees with the *Standards*, which emphasize that learning science should be based on inquiry and students examining what they already know and adding to their knowledge through questioning, experiences and experimentation. Motivated by these aims, researchers have begun to investigate the potential of using technology in a constructivist framework in classrooms. As curriculum and instruction combine constructed learning and integration of technology into teaching and learning practices, additional research is needed that will provide evidence of the

effectiveness of these strategies. This study examines the effects of using Geographic Information Systems (GIS), a new technology, on middle school students understanding of environmental content and GIS in a constructivist classroom.

MATHEMATICS EDUCATION REFORM

Aimed at describing the desired mathematics curriculum, The *National Council of Teachers of Mathematics Standards* (National Council of Teachers of Mathematics, 1986) focused mathematics education on problem solving with students engaged in relevant, non-routine problems that involved risk-taking and persistence. Students need to solve problems in all segments of their education and learn mathematics by modeling real-world situations. In so doing, they use critical thinking skills. Brain research shows that young children, especially in an inquiry context, can grasp mathematical and spatial concepts much earlier than previously thought (Spencer, Blades, & Morsley, 1989). One strategy being used to incorporate real world problem solving is the use of GIS in the science classroom (Kotulak, 2000). Science and mathematics are easily tied together when inquiry is used to solve real world problems. For example, in the MOSS and CITYgreen GIS units designed in this study, students use the major concepts described by the *National Council of Teachers of Mathematics Standards* of numeration, spatial sense, measurement, patterns, relationships, functions, data, probability, and statistics as they study their own environment in a way that is relevant to them.

TECHNOLOGY EDUCATION REFORM

The *Standards For Technological Literacy* (International Society for Technology in Education, 2000) emulate the science and mathematics standards by describing a classroom of the future that is student-centered, multimedia based, and in which active inquiry-based learning and critical thinking occur. In contrast, learning in the 1990s has been described as isolated and artificial (International Society for Technology in Education, 2000). This century should bring about change that makes the classroom of the last century a memory while creating the reality of the interactive classroom of the future. Students must think and learn by inquiring, problem-solving, and seeking information in order to be successful in the Information Age (International Society for Technology in Education, 2000) as described by the *National Science Education Standards* and the *National Council of Teachers of Mathematics Standards*. Using GIS in classroom instruction can not only help teachers and students learn important technology skills (Baker, 2002) but also how to teach *with* technology through analyzing information by addressing everyday relevant problem questions.

CONSTRUCTIVISM

In order fulfill the vision of the *Standards*, a method of instruction using scientific inquiry that draws upon the ideas of constructivism is needed (Baker, 2002). Learning research indicates that students acquire new knowledge through an active process of assimilation and accommodation, in which existing knowledge is transformed as students construct new meanings and understandings (Gadanidis, 1994). Teachers who recognize

that students are able to construct their own understandings provide a rich environment and context that allows students to test and apply their learning in new settings (Hassard, 1992).

In the effective classroom, constructing new meaning is done by tasks that are accomplished with the aid of a teacher-mentor or other students in a resource rich environment (Joyce & Weil, 1996). Teachers and students learn together as they question and investigate their environment. Learners should not be directly given knowledge or meaning; they must construct it from their own perceptions, experiments, experiences, understandings and inquiries. Through inquiry, learners have the opportunity to restructure information and connect new material to previously known information. Learners are actively involved in the problem solving process and verbalize how to solve problems to adults and their peers. Through this process, the learner is able to see connections and incorporate a deeper understanding and learning into their existing schema (Joyce & Weil, 1996).

INQUIRY IN SCIENCE EDUCATION

Scientific inquiry is fundamental to the science education reform movement. It is the dominant theme of the 1990s reform document *National Science Education Standards* (NRC, 1996) as well as the *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science, 1993). The development of scientific inquiry is considered to be the most effective way to create a society of scientifically literate citizens (NRC, 1996).

When engaged in inquiry, students describe objects and events, ask questions, construct explanations, and test those explanations against current scientific knowledge,

communicating their ideas to others (Bonnstetter, 1998). Inquiry learning includes such process skills as observing, classifying, measuring, predicting, inferring, summarizing, communicating, collecting data, analyzing data, drawing conclusions, building models, interpreting evidence, and experimenting. Through inquiry learning, problem solving strategies are employed to identify assumptions and consider alternative explanations (Swartz, 1996). In this way, students are actively developing their understanding of science by combining scientific knowledge with reasoning and thinking skills.

An inquiry-based science program according the *National Standards* consists of a combination of science content knowledge and the acquisition of science process skills as recommended by the National Science Foundation and the National Research Council (Wilke, 2002). In this study, three main areas are addressed that relate to students constructing their own understandings through inquiry: (1) the engagement of students in problem solving, (2) the use of technology to enhance scientific thinking, (3) an emphasis on experiencing science through real-world experiences in the environment.

ENVIRONMENTAL EDUCATION

Inquiry learning methods often address issues that are important to the community such as environmental issues (Westerlund, Garcia, Koke, Taylor, & Mason, 2002). It is believed that students will be able to discuss and make more informed decisions if they have developed reasoning skills through inquiry methods. Responsible environmental behavior has been cited as the ultimate goal of environmental education (Stapp, 1969).

Existing studies show that this goal is not being met in most schools in America (Volk, Hungerford, & Tomera, 1984).

Historically, environmental education has been an activity-based learning experience about the natural world involving primarily the life sciences through direct experiences such as role-playing activities (Haskins, 1999). More extensive project-based learning has not been common in environmental education. Environmental education needs to challenge students with more complex and complicated learning experiences through real-world problem solving (Gough, 1993). Place-based studies will provide meaningful experiences for students as they explore their local environments (Haskins, 1999). "Knowing who you are is impossible without knowing where you are" (Shepard, 1996). Coming into direct contact with natural space through the senses increases awareness of the inner and outer landscape. It is through direct experiences with place that knowing and caring will emerge (Haskins, 1999).

Environmental educators use an array of tools to enhance awareness of the environment such as binoculars, telescopes, and microscopes. Another powerful technology tool emerging to create a new awareness of place is GIS. Environmental scientists have long used computer-based technologies to visualize and monitor the environment (Shepard, 1996). This powerful software gives environmental educators a way to generate complex and accurate visual representations of the earth through maps. These mapping projects form communities of enhanced dialogs around visually interpreted information. Students can visualize "what if" scenarios leading to workable solutions. GIS technology empowers students to solve real-life problems and fosters a transformation in

students' self-esteem and value system, producing students with an environmental ethic (Ramirez & Althouse, 1995), which according to Hungerford, is the responsibility of environmental education (Hungerford, Peyton, & Wilke, 1980).

GIS And The National Standards

The use of data analysis technologies such as Geographic Information Systems (GIS) can be used as a method of teaching and learning in an inquiry-based classroom, as suggested by the *National Science Education Standards* (NRC, 1996). The *National Science Education Standards* encourage students' engagement in scientific investigations. "Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities" (NRC, 1996, p. 105). In this study, teachers and middle school students studied the environment with GIS on their school campuses. The six-week problem-based, inquiry GIS units called Mapping Our School Site (MOSS) and CITYgreen GIS used the *ArcView* program by Environmental Systems Research Institute (1996). Students asked problem questions, created experiments, analyzed the relationships between the abiotic and biotic components of the environment, formulated conclusions, and presented their results to their peers, encompassing the essential features of classroom inquiry (National Research Council, 2000).

GIS technology is a tool that empowers students to solve real-life problems as students identify problems, hypothesize, collect data, develop procedures, and produce workable results that they communicate to others (Ramirez & Althouse, 1995). The use of this technology supports scientific inquiry and problem solving and can foster complex

cognitive activities by students using sophisticated computer applications and data in an authentic learning environment (Baker, 2002). According to Environmental Systems Research Institute (1995), GIS can be a powerful tool for enhancing education as students and teachers work together to build coherent frameworks of the world around them. Audet and Paris (1996) in a report of the findings of a national survey of teachers using GIS, identified that teachers said, "GIS has significantly enhanced teaching and learning environments by enhancing problem solving, spatial data analysis, supporting interdisciplinary connections, and motivating students." These teachers predicted that GIS would be common in tomorrow's schools and become the tool of choice for exploring spatial concepts.

GIS And Environmental Education

Geographic Information Systems (GIS) permeates our everyday lives as an integral part of international, national, regional, state and local planning from emergency services to utilities, transportation to communications to global positioning systems (GPS). GIS is used in many ways, such as to coordinate census data, route buses, redistrict schools, and analyze crime and health statistics. The visual display of the locations and descriptions of the data has proven valuable when solving multi-faceted real-world problems such as those found in the environment.

The power of GIS lies behind its design for collecting, storing, manipulating, and displaying data referenced by a spatial or geographic component. Information is stored in layers that are linked to a map by geography. The user can change these maps or visual

representations of reality almost instantaneously. The layers may contain widely varying kinds of information that can be queried, combined, analyzed, and displayed to create new representations.

GIS is truly a real-world technology with multiple applications in environmental science to which students can contribute, becoming a part of the sustainable communities of the future. Students can visualize data, organize, store and analyze data from past years, easily manipulate data, and expand the scale of exploration, allowing them to search for and create multiple patterns and explanations. Thus, GIS can facilitate the combination and construction of numerous questions and answers through active inquiry as they investigate their environment. In fact, this technology can allow students to visualize environmental models that would have otherwise been too complicated for them to understand (Stubbs, Hagevik, & Hessler, 2003). Students also become more spatially aware and concerned about data quality (Sanders, Kajs, & Crawford, 2001). When students learn with GIS, they not only learn subject matter, they learn how to apply problem solving approaches (Bednarz, 2000). However, how to use new technologies like GIS in order to produce higher student achievement gains needs to be researched.

SPATIAL REASONING AND GIS

GIS is a spatial technology, requiring visual-spatial skills that are keys to success in today's increasingly high-tech society (Kotulak, 2000). Spatial thinking is the ability to manipulate three-dimensional objects in space and to see new relationships (Baker & Piburn, 1997). Spatial thinking can be defined as the ability to see your world in your

mind, to manipulate it and to explore it. Since interaction with the environment takes place in a three-dimensional space, the development of viable schemata of the world is linked to our spatial ability. Bybee & Sund (1990) state that spatial skills are essential to the development of high mental functions. This "new" way of thinking and learning from a spatial-visual approach is seldom addressed in instruction. Although textbooks are highly verbal, science relies heavily on visual images. Complex scientific relationships and principles can be more effectively communicated and understood through the use of visual images rather than with text alone. Pallrand and Seeber (1984) reported that spatial ability enhanced student's ability to make sense of data. Spatial ability has been linked to logical and scientific reasoning and mathematics competencies (Clements, Battista, Sarama, & Swaminathan, 1997). Could using GIS in schools emerge as a method of developing the spatial abilities of students?

BARRIERS TO IMPLEMENTATION

Despite these teachers' optimism, Kerski (2000) found in a survey of 1,500 American high schools that less than 2% were using GIS technologies even though 5% reported owning a GIS software package. Among teachers owning GIS software, half were not using it at all and of those teachers using GIS, only 20% had used it in more than one class for one lesson. Even though computers are now common in schools and classrooms across the United States, use of computers in science instruction has changed little from 1977 to 2000 (Horizon Research, 2000). In a National Survey of Science and Mathematics, fewer than 10 percent of science lessons included students using computers with only 20

percent of schools reporting access to computers as the problem. The chasm between the promise and the practice of GIS as an instructional technology in science classrooms indicates that there are other barriers contributing to lack of implementation in schools (Sanders et al., 2001).

Teachers integrating GIS successfully into their classrooms need to change their teaching styles from teacher-centered to more problem or project based learning. In fact, teachers who integrated GIS into their curriculum noticed a shift from more didactic methods of instruction to a more student-centered inquiry approach (Audet & Paris, 1996; Bednarz, 1999, 2000). It takes time to learn the software, to practice how to use it, and to implement GIS-based instruction in the classroom (Bednarz, 1999). In addition, there is a need for application expertise and support as teachers continue to integrate GIS and other spatial technologies into their curriculum (Environmental Systems Research Institute, 1997; McWillimas & Rooney, 1997). Additional research is needed that identifies and addresses these factors and investigates possible solutions to these problems.

RESEARCH QUESTIONS

Future success in the workplace may well require students to learn visual and technology related skills. Spatial reasoning skills are not only necessary for scientific research but these skills are also important to the successful use of technology. Teachers need training in ways to incorporate scientific inquiry and problem solving *with* technology in their classrooms. By teaching scientific concepts using spatial technologies such as GIS,

students may be able to develop their spatial-visual thinking skills and acquire new technology skills while learning important mathematics and science content.

This research examines students' and teachers' spatial reasoning abilities, teacher implementation of GIS in their classrooms, and student learning of environmental content with GIS. A thorough examination of the implementation of these GIS units and their effectiveness in classrooms can reveal practical strategies for future teaching and learning *with* GIS in schools.

Using both quantitative and qualitative research methods, this study specifically addresses the following research questions:

1) What effect does the Mapping Our School Site (MOSS) curriculum have on middle school students' learning of environmental concepts using Geographic Information Systems (GIS)?
    a) How do MOSS students compare to CITYgreen GIS students in their understanding of environmental concepts?
2) Is there a correlation between student learning and spatial reasoning, learning styles, and the use of Geographic Information Systems (GIS)?
    a) Which background experiences, such as academic courses (geometry, drafting classes), non-academic activities (toys, computer games), and sports are significant predictors of success on the Purdue Spatial Visualization Test: Rotations (PSVT:R) for teachers and middle school students using the Mapping Our School Site (MOSS) curriculum and the comparison CITYgreen GIS curriculum?
    b) Does gender interact with various success predictors of spatial reasoning?

c) Does learning style correlate with the success predictors of spatial reasoning?

d) Is there a relationship between learning style and the success predictors and the learning of the GIS curricula (MOSS and/or CITYgreen GIS)?

3) What is the likelihood of teachers implementing GIS in their classrooms after the weeklong GIS workshop and fall follow-up session?

a) To what degree are the GIS workshop teachers using GIS for classroom instruction the school year after the workshop?

CHAPTER TWO. LITERATURE REVIEW

The implementation of the *National Science Education Standards*, the *Standards for Technological Literacy*, and the *National Council of Teachers of Mathematics Standards* and the incorporation of technology and inquiry into the classroom motivated the research questions in this study. With the continued emergence of GIS and related spatial technologies, research should be conducted that reveals ways to best use this technology to increase student learning in science. In addition, the components of successful professional development in teaching with GIS need to be investigated in order to help teachers overcome barriers to using GIS in their classrooms. Finally, since spatial reasoning skills are important to student success in science and mathematics, ways to assess student spatial reasoning skills and dispositions should be explored.

The National Standards in science, mathematics, and technology emphasize real-world problem solving in which active inquiry-based learning and critical thinking occur. It is the union of science, mathematics, and technology that forms the scientific endeavor and makes it so successful (AAAS, 1990). However, the complex process of integrating science content and technology with mathematics in a meaningful, inquiry-based curriculum to enhance the learning of all students is a challenge to all science educators. This study addresses two such curricula and evaluates their success in integrating mathematics, science, and technology in an approach that addresses National Standards and creates a real world, problem-solving, inquiry based approach for teachers and students.

In this literature review, the theory and research related to student's cognitive processes when learning about the environment using the technology of Geographic

Information Systems is examined. The first section of the literature review begins with an examination of how students construct knowledge by solving problems using inquiry. Constructivism provides the theoretical framework for this study. The conceptual framework of skillful problem solving as described by Swartz (1996) and inquiry learning as described by Bonnstetter (1998) provide the basis for a working model to delineate and assess student's understandings of the environmental concepts discussed. Much of the recent research in science education emphasizes the benefits of teachers recognizing that students construct their own sense of meaning and understanding about a topic based on their prior knowledge. Conceptual change occurs as the students integrate concepts into a conceptual schema and transform the experience into a coherent system (Howe, 1996). Using a continuum of inquiry and blending the direct teaching of problem solving into the learning provides the scaffolding for conceptual change to occur. The first section of this literature review begins with a discussion of the constructivist theory of learning. The conceptual framework follows with an explanation of what is meant by using inquiry and problem solving to investigate the environment.

The second section of the literature review explores the role of spatial cognition and learning styles on an individual's ability to solve problems by understanding and analyzing patterns (Montello, 1997). The ability to manipulate mental images, a skill integral to spatial visualization, has been cited as fundamental to the understanding of science and can lead to enhanced problem solving abilities (Baker & Piburn, 1997). Geographic Information Systems is a visual representation of data that can enhance our ability to understand spatial processes and conceptual geographic ideas (Nellis, 1994).

The last section of the literature review examines research on teaching and learning with technology related to problem solving in science. In particular, this section discusses the results of using GIS in science education from teacher education to student learning.

THEORETICAL FRAMEWORK

CONSTRUCTIVISM

While it is true that constructivism is difficult to define and that many models have been proposed, constructivism is not any particular model, but something that looks like each of them under appropriate circumstances (Wertsh & Toma, 1995). The model in this study assumes that all knowledge is social in nature and that learning occurs in a context of social interactions that leads to understanding (Roehler & Cantlon, 1997). Learners cannot directly be given knowledge or meaning; they must construct it from their own perceptions, experiments, experience, understandings, and inquiry. Through inquiry, learners have opportunities to restructure information and connect new material with previously known information. Learners generate questions and gather information, as they are actively involved in the problem solving process. As the students verbalize how to solve problems, adults and peers may provide verbal cues that lead them to see the problem more clearly. If the cues are effective, students will see connections and be able to incorporate deeper understanding and learning into their existing schema.

According to Vygotsky, the area in which optimal learning can occur is called the zone of proximal development (ZPD). Wertsch (1985) defined the ZPD as: "The distance between the child's actual developmental level as determined by independent problem

solving and the higher level of potential development as determined through problem solving under adult guidance and in collaboration with more capable peers" (pp. 67-68). The assistance provided by an adult or more capable peer in the ZPD is called scaffolding and is characterized by the experiences and social interactions among students and teachers as they internalize knowledge, skills, and dispositions valuable for the learners (Rohler & Cantlon, 1997). The teacher or more capable peer guides the learner's emerging understanding and offers assistance as needed in this relationship. These activities fall into two realms, students working and independently constructing knowledge through some experience or students working with others to refine and construct their own knowledge (Baker, 2002). As the teacher and the students discuss the problems, students learn to think, construct, and clarify ideas. The group interaction allows students to recognize when their comprehension is not adequate and promotes the understanding that a number of different ideas are possible, although different from their own. The group clarification process and a shared information base deepen the comprehension of the individuals in the group (Hatano & Inagaki, 1991). The teacher and students co-construct knowledge, gain new understandings, and feel responsible for their own learning and the learning of others (Roehler, Hallenback, & Svoboda, 1996). Conceptual change occurs as the students integrate these concepts into a conceptual schema and transform the experience into a coherent system (Howe, 1996). Thus, the internalization process of learning begins on the social plane and moves to an inner plane where the information becomes a part of the individual's evolving knowledge base (Rohler & Cantlon, 1997).

Students must construct connections between different types and representations of data in order to create links that will help them to draw meaningful conclusions. There is a growing body of evidence that technology, when used in a constructivist environment, can help students to solve problems more effectively (Cates, 2000). A constructivist teacher understands that students create their own meanings. To assist in the creation, the teacher creates a learning environment that builds on prior experiences and co-constructs knowledge with students, asking for more explanations than they give to students. Through interacting with and carefully detecting learners' actions and language, a constructivist teacher can create a fine analysis of the specific nature of the conceptions of a learner. Most importantly, the formation of certain conceptions provides a basis for determining what the learner is ready to learn next and for hypothesizing what teaching activities (tools, problem situations) might foster that intended learning (Hagevik, Watson, & Tzur, 2003). Before examining the literature relating spatial cognition to the learning of GIS technologies, a conceptual framework is needed to establish a basis for analyzing students' understandings of environmental and GIS content.

CONCEPTUAL FRAMEWORK

Eisenhart (1991) describes a conceptual framework as a skeletal structure of justification, based on theory or experience, for adopting certain ideas that establish the research perspective and provide a guide for analysis and data interpretation. Inquiry and problem solving guided the analysis and data interpretation. The inquiry approach was

chosen because it allows students to construct without fear of rejection understandings through questioning strategies in which students reveal their constructions (Gibson, 1998).

Efforts to engage students in inquiry-based instruction date back to John Dewey (1938). Dewey believed that children learn by doing through extended experiences that involve discussions and real-world problem solving activities. The work of Dewey and others such as Bruner and Piaget in the 1950s and 1960s influenced the nature of curriculum development into the early 1970s (National Research Council, 2000). Studies conducted in the 70s and 80s found that inquiry-based science activities had positive effects on students' science achievement, cognitive development, laboratory skills, science process skills, and the understanding of the nature of science (Padilla, Okey, & Garrand, 1984; Purser & Renner, 1983; Schneider & Renner, 1980; Solomon, 1989; Wollman & Lawson, 1978) when compared to more traditional approaches. However, there is a danger in equating inquiry-based instruction with the currently accepted term of "hands-on science" (Crawford, 2000). To clarify this Bonnstetter (1998) described inquiry as an evolutionary process in which the roles of the teacher and student change as shown in Table 1.

Table 1: Inquiry Evolution (Bonnstetter, 1998)

	Traditional Hands-on	Structured Inquiry	Guided Inquiry	Student Directed Inquiry	Student Research
Topic	Teacher	Teacher	Teacher	Teacher	Teacher/ Student
Question	Teacher	Teacher	Teacher	Teacher/ Student	Student
Materials	Teacher	Teacher	Teacher	Student	Student
Procedure/ Design	Teacher	Teacher	Teacher/ Student	Student	Student
Result/Analysis	Teacher	Teacher/Student	Student	Student	Student
Conclusions	Teacher	Student	Student	Student	Student

Teacher Controlled----------Student Controlled

Exogenous----------Cognitive Development----------Endogenous

Focus on Teaching----------Focus on Learning

The *National Science Education Standards* (NRC, 1996) state that the main focus of science education should be inquiry. When engaged in inquiry, students describe objects and events, ask questions, construct explanations, and test those explanations against current scientific knowledge, communicating their ideas to others (Bonnstetter, 1998). They use problem solving strategies to identify assumptions and consider alternative explanations (Swartz, 1996). In this way, students are actively developing their understanding of science by combining scientific knowledge with reasoning and thinking skills. Science Teaching Standard A states that, "Teachers of science plan an inquiry-based science program for their students" (NRC 2000, p. 22). Inquiry learning can be defined as the student-based exploration of an authentic problem using the processes and tools of the discipline or content (Wilke, 2002). Process skills may include observing, classifying, measuring, predicting, inferring, summarizing, communicating, collecting data, analyzing data, drawing conclusions, building models, interpreting evidence, and experimenting.

Student comprehension of content knowledge and the acquisition of science process skills are relevant goals that are necessary in inquiry learning and are strongly recommended by the National Science Foundation and the National Research Council (Wilke, 2002).

Bonnstetter (1998) believes that the NRC *Standards* suggest inquiry activities at the student-directed level. Inquiry learning requires students to go beyond science process skills and to "mesh" scientific processes with scientific knowledge as they use reasoning and critical thinking to develop their understandings (NRC 2000, p. 18). These abilities include (a) identifying questions and concepts, (b) designing and conducting investigations, (c) using technology and mathematics, (d) formulating explanations and models using logic and evidence, (e) recognizing and analyzing alternative explanations, and (f) communicating and defending their findings. To develop these abilities, students should be learning science through applications that use data to investigate and analyze questions over extended periods of time and model real world situations (NRC 1996, p. 113). The MOSS and CITYgreen GIS curriculum used in this study employs the principles of inquiry and teach students to solve problems skillfully using technology in real world situations.

SKILLFUL PROBLEM SOLVING

Using inquiry and problem solving as a goal of instruction finds support throughout the science community (American Association for the Advancement of Science: Project 2061, 1990). Some of the features of science described in *Science For All Americans* include that scientific ideas are subject to revision, cannot provide complete answers, are based on evidence, are not authoritarian, and are a blend of logic and imagination. The problem solving approach used in this study, called infusion (Swartz & Parks, 1994),

employs the direct teaching of thinking skills blended into the inquiry-based science lessons. "Infusion integrates direct instruction in specific thinking skills into content area lessons. Lessons improve student thinking and enhance content learning" (Swartz and Parks, 1994, p. 9).

Problem solving requires the use of a variety of critical thinking skills such as prediction, generating possibilities, classification, reliability and accuracy of observations and information, and comparing and contrasting. Verbal and graphic maps were used to guide students through the steps of skillful problem solving (Appendix C). The steps of skillful problem solving include identifying a situation as problematic, defining the problem, generating and assessing possible solutions, and implementing the problem solutions (Swartz and Parks, 1994, p.70 - 72). Therefore, it is not enough to give students problems to solve. They must be taught, through the use of guided questions, to develop the habits of skillful problem solving (Perkins & Swartz, 1992). Using skillful problem solving challenges students with authentic problems whose solutions require content knowledge and conceptual understanding. The problem solving process becomes infused into the inquiry-based science instruction. Learning through problem solving creates a rich atmosphere in which an active constructive process that connects concepts and ideas can be applied (Swartz, 1996). In a study done by Foote (1997), integrating problem solving into the teaching of GIS sharpened students' analytical reasoning abilities. In addition, Chen (1997) found that this approach provided a setting for active inquiry-based learning and opportunities for cooperative group work. This study involved students working together in cooperative groups using GIS to solve problems. Figure 1 illustrates the implementation

process of using problem solving and GIS in an inquiry-based science investigation. The model proposed by Chen (1997) was modified and combined with the steps of skillful problem solving by Swartz (1996), which are in italics in Figure 1. The five sequential execution steps are mutually dependent, as indicated by the double-direction arrows.

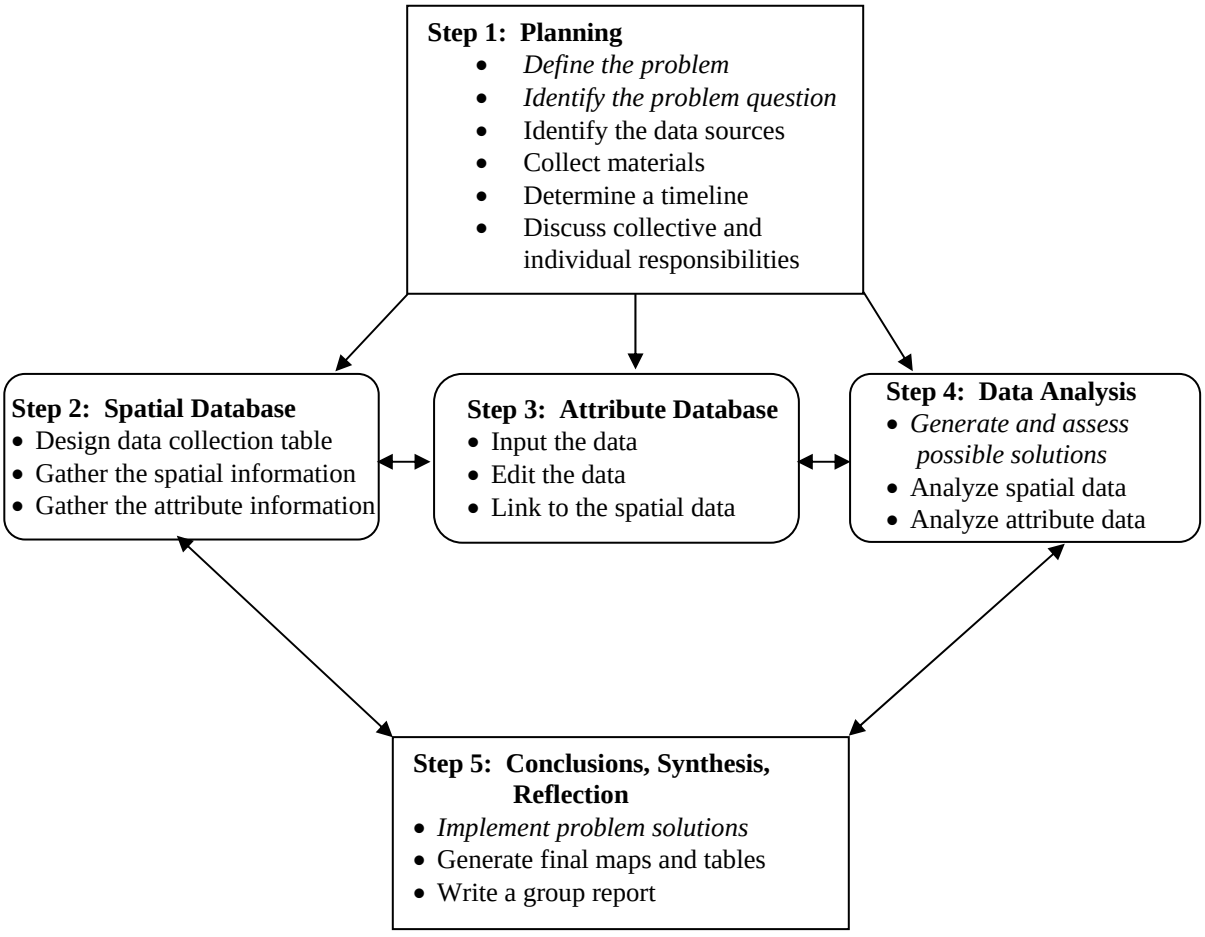


Figure 1: Problem solving and GIS (Chen, 1997; Swartz & Parks, 1994)

Planning – Step 1

Planning and design is the first step and most critical step in planning an inquiry-based GIS problem solving scientific investigation. Students defined and identified

problem questions. Both of the GIS curricula in this study involve this step, however, students in the experimental group were able to explore in greater depth problem questions that interested them. Foote (1997) noted that interesting research problems helped capture students' attention and expand their "intellectual horizons".

Spatial Database – Step 2

Students gathered spatial and attribute information relevant to their problem question. From the second to fourth step, students used GIS to perform spatial analyses and to find answers to their questions. The comparison group used predetermined data tables and procedures to collect their data. The experimental group designed data tables to match their individual problem questions. Students gained technical skills as well as important science process skills as they worked together to investigate their problems.

Attribute Database – Step 3

After collecting the data, it is put into a table using a spreadsheet software program. The data is then imported into a GIS program for analyses. The table in the GIS program is now called an attribute table because it is associated with visual features on the map. Frequently when students use GIS to visualize their data, they find unknown discrepancies and have to recollect and edit the attribute table.

Data Analysis – Step 4

Spatial and attribute data analyses using GIS generated possible spatial patterns that were assessed in order to formulate solutions. Chen (1997) expounds on the importance of problem solvers understanding the underlying reasoning behind the GIS operations. "They

should drive the software through insightful hypotheses and clear statements of purpose, not let the software control the process through blind acceptance of defaults and programmed command streams" (Chen, 1997, p. 263). In a study done by Audet (1994), problem-solving approaches of college level novice students were compared to expert GIS users (R. Audet & G. L. Abegg, 1996). Students answered questions using *ArcView* GIS, (Environmental Systems Research Institute, 1996), and results were evaluated through naturalistic research methods that revealed thematic components. His findings confirmed that novices are more likely to focus on the surface features of the problem, use trial and error strategies, be affected by personal interpretations of vocabulary, act before shaping a full strategy, continue to work without verification, change their style frequently, and experiment with icons and tools. The GIS experts demonstrated a greater tendency to conceptualize the problem, make consistent logical queries, work with fewer errors, complete problems quickly, integrate GIS into their existing schemata, and ask questions about their performance compared to their peers. Audet's study (1994) offers some insight into how expert GIS users solve problems. For example, as the student GIS groups conducted their GIS spatial and attribute data analyses, they documented the analyses they performed. Both groups generated and assessed possible solutions. Documentation of the GIS analysis procedures provided valuable information regarding thinking strategies used in order to compare both groups' abilities.

Conclusions, Synthesis, Reflection – Step 5

In the last step, students reviewed their projects and reflected upon possible solutions to their problem questions. They analyzed what they learned and documented

their conclusions in a report and presentation to their classmates. Both the MOSS and CITYgreen GIS comparison groups produced a report and a map of their conclusions (Appendix R) and presented their findings to their peers.

There is a growing body of evidence in the literature indicating the use of problem solving, inquiry-based learning using GIS technology. It has been documented that active learning in groups in higher education could challenge students to learn and empower them to think (Anderson, 1997; Burkill, 1997). A well-planned, problem solving approach has been shown to enhance student understanding of content and GIS (Chen, 1997) but the discussion continues on ways to integrate problem solving and inquiry using such technologies as GIS (Goodchild & Kemp, 1991). To date, no studies have examined the effects of using GIS in a problem solving, inquiry-based approach on student understanding of content and GIS in K-12 education. However, evidence has suggested that inquiry-based learning in which students solved real problems improved students' abilities to understand science content and process skills (Solomon, 1989, Padilla, Okey, & Garrand, 1984; Purser & Renner, 1983). Table 2 illustrates the relationship between problem solving, GIS and inquiry-based learning.

Table 2: Relationship Between GIS, Problem Solving and Inquiry-based Learning

Knowledge and Skill	Inquiry Process
1. Planning	1. Topic/Question
2. Spatial Database	2. Materials
3. Attribute Database	3. Procedure/Design
4. Data Analysis	4. Analysis/Results
5. Conclusion, Reflection, Report	5. Conclusions
GIS and Problem solving (Chen, 1997; Swartz & Parks, 1994)	**Inquiry-based learning (Bonnstetter, 1998)**

During the planning stage, students solving real problems research related content as they decide upon a topic and problem question to study. Students discuss background information regarding the facts of the problem. Students may have to learn other content and technical skills as they use scientific equipment necessary to their study. The data collection table is designed, including the spatial information, depending on the procedure of the study. After completing the fieldwork, the spatial data is then entered into a geodatabase so that it can be analyzed in order to search for patterns and develop inferences. Additional research and acquisition of new content understandings occur at this stage. Finally, as a result of reflection, conclusions and additional questions revealed by the study are identified and presented to others for discussion and further investigation. Chen (1997) found that college students gained a better understanding of using GIS to answer spatial questions using the project-oriented approach. Students were given a chance to apply their knowledge, manage a project, work in a groups, write a research report, and to communicate their findings to others. Students reported that they gained skills important to employment after their studies.

The next section of the literature review examines studies that relate the role of spatial cognition and learning styles to an individual's ability to solve scientific problems using technologies such as GIS.

SPATIAL COGNITION IN SCIENCE

The importance of the visual-spatial aspect of science is widely known yet seldom addressed in science instruction (Baker & Piburn, 1997). The ability to view the world from multiple perspectives is fundamental to the development of many important scientific concepts. Einstein's ability to imagine the world from the perspective of someone riding a beam of light contributed to the development of the theory of relativity (Baker & Piburn, 1997) and Tesla's ability to mentally build, operate and test machines led to many of his inventions (Mathewson, 1999). Science relies heavily on visual images. Complex scientific relationships and principles can be more effectively communicated and understood through the use of visual images (Baker & Piburn, 1997). Using GIS, the perceptions of large amounts of information can be condensed and visualized. Understanding relationships through visualizations has been recognized as critical to the development of expertise when using GIS to solve problems (R. H. Audet & G. L. Abegg, 1996).

Typically, science instruction does not focus on the development of spatial cognition; by ignoring this critical element we may be limiting the understanding of our students. The ability to manipulate objects mentally has been found by Baker & Piburn (1997) to enhance problem-solving abilities. Pallrand and Seeber (1984) reported that

spatial ability enhanced student's ability to make sense of data. Spatial ability has been linked to logical and scientific reasoning and mathematics competencies (Clements et al., 1997). Since, from a constructivist perspective, interaction with the environment takes place in a three-dimensional space, the development of viable schemata of the world is linked to our spatial ability. Bybee & Sund (1990) state that spatial skills are key to the development of high mental functions. Fundamental research is needed that relates how spatial cognition can be developed through science instruction and the impact of the visual-spatial approach to the learning of science (Greca & Moreira, 2001).

SPATIAL REASONING ABILITIES

Spatial reasoning can be defined as the ability to see your world in your mind, to manipulate it, and to explore it (Baker & Piburn, 1997). During the last 100 years psychologists have administered spatial ability measures through a battery of tests like the ones used to evaluate intelligence. Misconceptions from these initial tests regarding spatial reasoning include:

- Spatial ability is only important in a narrow range of applications.
- People are born with spatial ability, it cannot be taught.
- Spatial activities in the classroom are too time-consuming and really do not pay off.
- What's really important is logic and problem solving ability.
- Hormonal changes that occur during puberty cause men to be much better at this type of thinking than women. (p. 166)

Increasingly educators are now realizing that children need spatial reasoning skills to learn abstract concepts in schools. In fact, many experts now believe that this ability can

be developed and taught and when used properly and can help children understand difficult abstract concepts (Clements et al., 1997). Brain research shows that young children can grasp mathematical and spatial concepts much earlier than previously thought (Spencer et al., 1989). This type of instruction is showing promise especially for students who do not normally achieve in school (Kotulak, 2000). Many educators and researchers, such as those at the University of Chicago (Kotulak, 2000), are now recommending the incorporation of spatial reasoning skills into daily classroom instruction. One strategy being used to accomplish this goal is the incorporation of "real world" problem solving into classroom lessons (Kotulak, 2000). Spatial reasoning is not just a way of helping children become smarter. The information age is demanding that students be able to manipulate three-dimensional objects in space and to see new relationships. In fact, many believe that spatial reasoning skills are the key to success in today's increasingly high-tech society (Kotulak, 2000).

The first systematic research of spatial ability was done in the 1920's and 30's as psychologists began to identify aspects of general intelligence. Researchers often identified spatial factors and separated them from numerical and verbal factors (McGee, 1979). L. L. Thurstone defined the "space" factor (SF) as "the ability to visualize flat figures and objects in three-dimensions and to see the relationships of forms" (Engle & Snellgrove, 1979). However, an attempt to define spatial terms is difficult and confusing and often duplication of terms occurs. In this study, spatial reasoning refers to the construction of mental representations and the mental transformations that we perform on them to engage in

reasoning and problem solving (DeVega, Peterson, Johnson-Laird, Denis, & Marschard, 1996).

Technical Courses and Spatial Reasoning

Paterson et al. in a 1930 study found that spatial tests were useful in predicting success in junior high school technical courses (McGee, 1979). His results were not correlated to an Otis Intelligence Test (-.07). Another similar study done in 1964 showed a high correlation of spatial ability to success in metalwork, woodwork, handicraft, and drawing. In addition these tests were also found to be the best predictors of grades in mathematics and vocational-technical courses. Spatial ability is important in many science-related fields such as engineering, drafting, and designing (McGee, 1979).

Gender

McGee (1979) states that the "widely documented sex difference on tests of spatial visualization and spatial orientation, as well as on numerous tasks requiring spatial abilities, does not reliably appear until puberty" (p. 41). There is empirical evidence that supports sex differences in spatial abilities. "A girl between the ages of 12 and 14, or when puberty is occurring, who wishes to enter a field requiring high-level spatial skills would need to obtain a very high score in relation to other girls in order to be competitive with boys her age" (McGee, 1979, p. 45). This study takes into consideration age and gender as factors that could possibly affect spatial reasoning ability.

McGee (1979) also considered environmental factors in his study of spatial reasoning ability. Berry (1966) studied Temne Eskimo females and showed they had no differences in spatial ability from their male counterparts. Eskimo females shared equally

in hunting and navigating, showing the importance of experience in spatial ability. However, McGee agrees with research conducted later by Gimmestad (1990), and Baenninger and Newcombe (1989) that training does not eliminate differences, but rather improves scores of both male and female students. Kimura (1992) explains, “Men, on average, perform better than women on certain spatial tasks. They outperform women in mathematical reasoning tests and in navigating their way through a route." Kimura (1992) further explains that specialization due to thousands of years of humans living as hunter-gathers in which the men were responsible for hunting and defense and women for gathering food and caring for children could also explain these differences. He argues that this may be the reason women have been found to use landmarks as a strategy to orient themselves, outperforming men in mathematics calculations and certain precision manual tasks. In a study by Nordvik and Amponsah (1998), gender differences in spatial ability were found among white, Norwegian-born, technology and social science students. There is neurological evidence that supports that the male brain is different from the female brain and that the male brain is functionally more asymmetric. As a result of these research findings, gender, handedness, and spatial experiences were considered as possible contributors to spatial ability in this study.

Environmental Cognition

Despite the evidences of 100 years of psychological research, in the early 1990’s, some psychologists changed the way they approached visual-spatial cognition. Spencer et al. (1989) defined the term “environmental cognition” and proposed that individual differences in spatial cognition may arise from interactions with the environment. Hart

(1979) showed that environmental knowledge is directly related to a child's activity range. He found that boys who were allowed greater movement than girls developed more knowledge regarding the world around them. Other factors such as car ownership and the degree in which an individual feels involved in their neighborhood have also been associated with environmental knowledge (Spencer et al., 1989). Could cultural stereotypes in which females under-perform on spatial tasks lower expectations of successful performance? How much does sex, age, or experience contribute to an individual's visual spatial cognition? Newcombe (2000) challenges, "If sex-related differences are apparent early in childhood, this may be because children's play is already sex-typed and boys get more experience with spatial activities, rather than because the differences are biological". Idle et al. (1993) found that feminine toys were preferred for girls and masculine toys preferred for boys even though both parents preferred to play with their children using masculine toys. Since it is the parents who select and purchase toys early in their children's lives, regardless of sex, parents need to choose toys that will develop their children's spatial abilities. Toys, sports, and computer games played by participants in this study were considered as possible factors that contributed to spatial experience.

Kalichman (1989) incorporated views from both sides in suggesting an interactive theory in which both genetic and cultural factors play a part in the development of spatial skills. Environmental reinforcement and self-selection of experiences to create sex-related differences could magnify small initial differences between sexes. Biological variables could be acting in complex socially mediated ways. Timing of maturation could also cause variation in the type of activities people engage in and the personalities that develop

(Newcombe & Huttenlocher, 2000). Ben-Chaim et al. (1988) found that the optimal time for the teaching of spatial visualization tasks was the seventh grade before the increasing gap between boys and girls which begins between grade 7 and 8. Deno (1995) found a significant correlation among spatial ability in men and participation in all building type activities such as playing with Legos®, log building sets, and organized gymnastics. Women had significant positive correlation between spatial performance and activities such as watching educational television shows like *Sesame Stree*t for example. This study did not include the 312 items tested by Deno (1995) but instead focused on the general categories of academic courses (geometry, drafting classes), non-academic activities (toys, computer games) and sports.

Interactonist thinking takes into consideration the neonatal starting points for cognitive development, biological maturation, knowledge gained from an individual's interaction with the environment, and the contributions that social interactions transmit to culturally amplify cognition. Researchers need to go beyond the statement that "biological and social forces interact" to the specific testing of models (Newcombe & Huttenlocher, 2000). By developing models, we can better understand changes that should be made in teaching children resulting in the development of improved spatial ability.

THE PURDUE SPATIAL VISUALIZATION TEST: ROTATIONS (PSVT:R)

Until recently, few studies had been conducted to determine the best way to measure an individual's spatial visualization ability. Within the last ten years researchers have tried to determine methods for measuring spatial ability and techniques for improving it (Bertoline & Miller, 1990; Deno, 1995; Miller, 1992; Sorby & Baartmans, 1996; Wiebe,

1993). Chin (1993) conducted a study in which a panel of experts was asked to identify research currently underway and the nature of research that should be undertaken in the future related to engineering graphics. The panel concluded, "the data tends to suggest that additional efforts need to be directed at research in the areas of visualization and computers" (p. 15). Within the last five years, an interest in geographic cognition has developed within the Geographic Information community. The National Center for Geographic Information and Analysis (NCGIA, 1996) recognizes the intersection between spatial visualization and GIS and describes future research priorities as representations, scale, spatial analysis, and uncertainty.

Spatial abilities have been shown to be an important component of success in many engineering, mathematical and scientific professions (Miller & Bertoline, 1991). What is difficult to determine is the type of spatial ability being used to predict success. According to McGee (1979) and Tartre (1990) there is more than one type of spatial ability. Spatial visualization involves being able to mentally manipulate, rotate, twist or invert pictures when presented with a visual stimulus. One must be able to recognize, retain, and recall a configuration of an object that has been manipulated in three-dimensional space. Spatial orientation, on the other hand, involves the arrangement of components within a visual stimulus pattern or the ability to remain unconfused when the orientation of the stimuli changes. Spatial orientation is "the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem" (McGee 1979, pp. 3-4).

Lohman (1988) introduced a third factor referred to as speeded rotation, part of mental rotations of forms or objects in motion. Objects used to test this factor are simple

because it is the speed of rotation that becomes important. In an attempt to clarify different types of spatial abilities, Tartre (1990, pp. 29-43) devised a classification scheme categorizing spatial skills as follows in Figure 2.

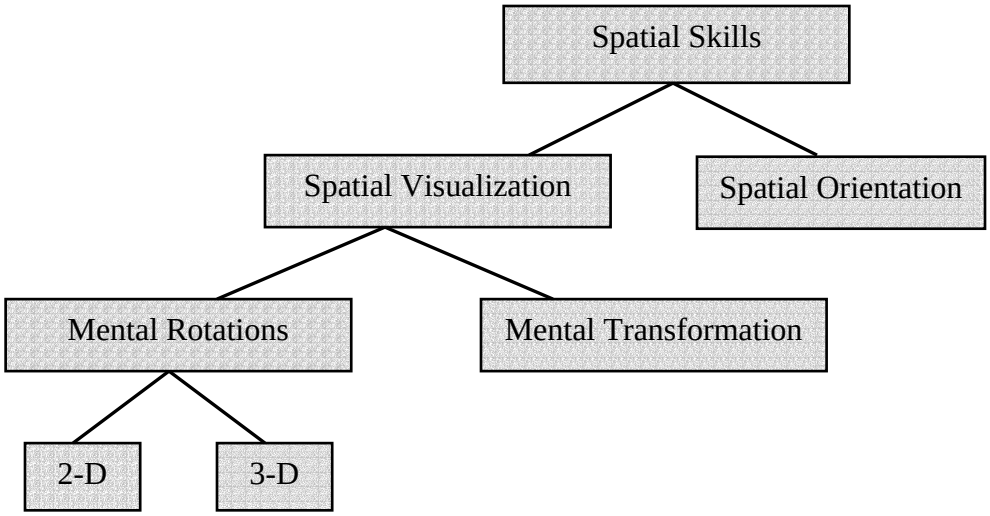


Figure 2: Tarte (1990) Spatial Skills Classification System

In Tartre's scheme spatial visualization is subdivided into two categories, mental rotations and mental transformations. Mental transformations refer to only part of the object being mentally altered. Mental rotation is also further subdivided into two-dimensional and three-dimensional ability. The Purdue Spatial Visualization Test: Rotations (PSVT:R) is designed to measure the ability to perform 3-D mental rotations.

There are many tests that claim to measure an individual's spatial ability. However, research shows that these tests do not all measure the same type of spatial ability. The PSVT:R (R.B. Guay, 1977) and the Mental Rotations Test (Shepard & Metzler, 1971; Vandenberg & Kuse, 1978) have a high construct validity (KR-20 reported between .80

and .92) in spatial visualization ability (Guay, 1980). The Revised Minnesota Paper Form Board Test (Likert & Quasha, 1970) seems to measure spatial orientation and requires a high degree of analytical processing (Guay, McDaniel, & Angelo, 1978). There is also evidence supporting the Spatial Ability section of the Differential Aptitude Test (Bennett, Seashore, & Westman, 1981) as a measure of spatial orientation ability (Juhel, 1991; Kovac, 1989). Correlations among tests of spatial ability are highly variable, suggesting that different tests are measuring different types of spatial abilities (Paivio, 1986). Since the types of activities that take place when creating cognitive maps and using GIS rely upon an individual's spatial visualization ability, research suggests that the PSVT:R and the MST are the best measures of this construct.

Branoff (1998; 1999) conducted two studies involving undergraduate students enrolled in introductory Graphic Communication courses at North Carolina State University involving the effects of coordinate axes on spatial visualization ability using the PSVT: R for assessment. Branoff suggested that higher male scores as compared to female scores on the PSVT: R were from the use of different processing strategies. He hypothesized that males employed a more holistic method while females used analytical techniques, which slowed the rotation rate. By labeling the coordinate axes as x, y, and z on the PSVT:R, there was no significant score difference between males and females in either study. In a follow-up study, Branoff (2000) researched the validity and reliability of the revised PSVT:R using 277 undergraduate students and found that there was no significant difference between the comparison group and the experimental group, which used the trimetric pictorials. Furthermore, a correlation between the MRT and the two versions of

the PSVT:R showed consistency in measurement between the tests. The reliability of the revised PSVT:R was determined using the Kuder-Richardson 20 (KR-20) coefficients which were calculated for the original PSVT:R and the revised PSVT:R. The value of 0.83 was consistent with previous research regarding KR-20 reliability. Based on statistical analyses it was determined that the revised PSVT:R was as good a measure of spatial visualization ability as the original PSVT:R.

This study used the revised PSVT:R (Appendix H) developed by Branoff to measure the spatial visualization ability of teachers and students. Using labeled coordinate axes eliminated gender differences previously found using this test. In addition, to eliminate age differences, participants taking the test were given unlimited time to complete the test, though most participants completed the 30 item test in one class period or 55 minutes.

SPATIAL EXPERIENCE SURVEY (SES)

A spatial experience survey (SES) was developed by Deno (1995) and Parolini (1994) for the purpose of determining the importance of prior experiences on spatial reasoning abilities. Deno's SES was developed by compiling a list of previously validated spatial activities from research done at Purdue University (R. B. Guay, 1977; Guay & McDaniel, 1979), Pennsylvania State University (Newcombe, 1982; Newcombe & Huttenlocher, 2000) and the University of Maryland (Olson, 1985). The SES contained three major divisions, formal academics, non-academics, and sports, which were further divided into 12 categories with 480 possible spatial activities. Results were correlated to scores on the Mental Rotations Test (MRT) for spatial visualization. Non-academic

activities were found to be the highest predictor of spatial reasoning success with items such as playing with Legos® and log building sets, participating in art activities, repairing or building items such as bicycles or woodworking, and participating in organized gymnastics or watching *Sesame Street* being the most significant. Among the 396 beginning engineering college graphics students who took the SES, no gender differences were found. The test was highly reliable with a Cronbach's Coefficient Alpha of 0.74.

In Parolini's (1994) SES, handedness was also considered. There is some research that indicates that left-handers may have an advantage over right-handers because of a more adapted right hemisphere of the brain (Levy & Reid, 1978). Similar to Deno's study, Parolini also included spatial experiences in school such as courses in drafting, art, design, and shop as well as geometry mathematics courses. Based on the studies of Newcombe (2000) and the importance of movement in space, levels of participation in sports were included. An important addition to Parolini's SES is the inclusion of computer and video games. Tarte (1990) in a study of 58 Harvard students, found that after playing video games for only 5 hours, female spatial visualization scores increased dramatically. In 1993, 1,012 incoming engineering freshman took Parolini's SES, which consisted of a 14 item questionnaire. Results were correlated to scores on the PSVT: R for spatial visualization. Experiences in courses such as mechanical drawing, drafting, CAD drawing, and art were shown to be predictors of success on the PSVT:R. In addition experience with toys such as blocks, Legos, and other building toys, as well as time spent playing video/computer games were found to be important predictors of success. Gender was significant but this could have been due to the PSVT:R test used rather than the SES (Branoff, 1998).

In this study, a Spatial Reasoning Inventory (SES) was developed from the results of these two studies and administered to adults (Appendix I) and a modified version administered to students (Appendix J) along with the 30 item revised PSVT:R (Appendix H). Items on the SES were broken down into the following three categories, background experiences such as academic courses (geometry, drafting classes), non-academic activities (toys, computer games), and sports activities. Gender, age and handedness were also included. The twelve-item SES was administered to 12 teachers the first day of the workshop and an eleven-item SES was administered to each student before beginning the GIS curriculum. Participants took the SES online and results were e-mailed to the researcher.

LEARNING STYLES INVENTORY (LSI)

The ways in which an individual characteristically acquires, retains, and retrieves information are collectively called an individual's learning style (Felder & Henriques, 1995). Learning styles have been extensively discussed in the educational and psychology literature (Claxton & Murrell, 1987; Schmeck, 1988), and over 30 learning style assessment instruments have been developed in the last three decades (Guild & Garger, 1985). The type of assessment selected depends on the aspect of the individual's learning that is applicable. Each model assesses a different aspect of the whole learner (Armstrong, 1994). Examples of learning style models include the Theory of Multiple Intelligences by Howard Gardner (Gardner, 1993), a cognitive model that suggests that each person possesses several intelligences, the Myers-Briggs Type Indicator (Myers & McCaulley, 1985) based on the work of Carl Jung, which measures the affective dimensions of learning, the VARK

Learning Styles Inventory developed by Neil Fleming (2002), which provides a perceptual learning style profile, and the Visual-Auditory-Kinesthetic Model (Barbe, Swassing, & Milone, 1981), which focuses on modes through which individuals take in and process information (Miller, 2001).

Students with different learning styles approach and learn information in different ways (Roark, 1998). They have preferred ways of processing and organizing information. An individual's learning styles are unique and permanent, transcending socio-economic status and intelligence (Vail, 1992), but each person has more than one way of learning. Most individuals have predominant clusters, preferred channels, and secondary and subordinate approaches to learning (Vail, 1992). Understanding learning styles is important to classroom instruction because research shows that student motivation and performance improves when instruction is adapted to student learning preferences and styles (Miller, 2001).

While some learning styles inventories are diagnostic, such as the Myers-Briggs Type Indicator, the Learning Styles Inventory (LSI) used in this study (Appendix K) identifies the general preferences of three types of learners, auditory, visual, and kinesthetic. According to research conducted by Lloyd Rieber (1994), 45% of students in schools are visual learners. Felder and Silverman (1988) found that most engineering students are visual learners. Rieber (1994) believes that learning environments that are computer-based benefit the visual learner more than any other learning style. Highly visual computer-based environments allow individuals to grapple with sophisticated ideas from mathematics and science in visual ways that are instantaneously concrete. GIS is an

example of a visual computer-based modeling program. People learn most effectively with one of the three modalities, visual, kinesthetic, or auditory, and miss or ignore information presented in the other two (Felder & Silverman, 1988). Research has shown that both motivation and achievement improve when learning styles are matched and that students learn best through actual experience (Miller, 2001; Willis & Hodson, 1999; Wilson, 1998). The use of GIS in classroom instruction could appeal more to those individuals who are visual learners than those who are kinesthetic or auditory learners.

The online LSI used in this study was based on the research of Tindall (1980) and Matthews (2003) of North Carolina State University. The forty statements are marked if the individual agrees with the statement and the box is left empty if the individual disagrees. After the submit button is selected, the results and an explanation are e-mailed to the researcher and the individual. Items identified as "A" responses on the result form indicate an auditory preference and "B" responses a visual preference. If as many "A" responses as "B" responses are chosen or if they are within one of each other, the individual is a kinesthetic learner. Matthews (2003) of North Carolina State University involving undergraduate graphics students identified that students that had both auditory and visual preferences were most often kinesthetic learners. Descriptions of the three possible modes of learning identified by this inventory are described in Table 3.

Table 3: Descriptions of LSI Three Modes of Learning

Learning Style	Traits
Visual	Remember more of what they see with their eyes like sights, pictures, diagrams, films, flowcharts, and symbols.
Kinesthetic	Involves both information perception (touch, taste, smell) and information processing (moving, relating, doing something, active) while learning.
Auditory	Remember much of what they hear and more of what they hear and say. They love discussion and prefer verbal explanation to visual demonstration. They learn well by explaining things to others.

All items on the inventory were phrased positively with twenty possible verbal responses and twenty possible visual responses. Only chosen or true responses were counted toward the score. A 30 item-scale analysis of a similar verbal and visual learning styles questionnaire indicated that alpha coefficients for the verbal and visual scale were .70 and .59 respectively. The two sets of items measuring the two learning preferences were shown to possess good construct validity and adequate reliability (Kirby, Moore, & Schofield, 1988).

The last section of the literature review examines research on teaching and learning with technology. In particular, the results of using GIS in science education from teacher education to student learning will be discussed.

GEOGRAPHIC INFORMATION SYSTEMS

GIS, a tool commonly used by adult professionals, has the potential to enhance learning and empower students to solve real-life problems. The interdisciplinary use of this technology combines a wide range of specialties such as remote sensing, geography, cartography, geology, surveying, photogrammetry, and computer science (Deal, 1998). Ten years ago, GIS was only available to persons with special skills and powerful mainframe computers. Now, due to rapid technological advances, GIS applications are available to everyone with minimal investment in hardware or software (Deal, 1998). Maps, images, and locational map features such as those found using Global Positioning System (GPS) combined with databases, provide an intelligent view of the world around us. The information, stored as a collection of geographically referenced thematic layers (such as buildings, streets, water, trees and so on), are linked to information or descriptions about features in the layers (such as Lake Michigan in the water layer). The multiple layers of map representations and descriptions allow for an infinite number of connections and analyses. The instantaneous visualizations by the users and his or her ability to interact with the maps in a dynamic environment appeals to adults and students using the technology (MacEachren, 1994).

Database technologies such as GIS have significantly changed the way data is collected, stored, distributed and used, resulting in a need for trained and experienced Information Technology (IT) workers. Daratech (2003) announced a 8% growth in the GIS industry as compared to the year 2000, with the market for GIS software totaling $1.7 billion. The demand outpaces the supply for environmental engineers and environmental

technologists who have a strong grasp of visual-spatial technologies such as GIS (Baker, 2002). Resources such as wildlife habitats, rivers, recreational areas, agricultural land, and forests are being studied, assessed, and managed using GIS technologies. These and many other GIS projects and information can be found on the Internet where anyone can gain access to the information. Data sharing and collaborations are helping change and improvement to occur. For example, the citizens in Minneapolis-St. Paul debated the preservation of open space and the expansion of roads by visualizing scenarios using interactive GIS maps and data over the Internet (Landkamer, 2003). Databases combined with other imaging technologies have changed the way we view our world (Deal, 1998). The knowledge of how to use and visualize data has become an important skill in today's world for adults and students.

GIS IN K-12 EDUCATION

As early as 1992, the Secondary Education Project from the National Center for Geographic Information Analysis began to look at ways that GIS could be incorporated into schools. It was not until 1994, with the development of educational projects such as World Watcher from Northwestern University and Mapping Our City from Technology Education Research Consortium (TERC), that the adaptation of GIS for use in the K-12 classroom really began (McWillimas & Rooney, 1997). Initial efforts focused on simplification of the GIS interface to help students focus on content rather than the learning of the technology.

In 1995, Pennsylvania State University's GeoVista program and TERC collaborated on a project using remotely sensed data and aerial photography. Five areas of research were identified including; scale, three-dimensional representations, symbol representation,

point of view, and change over time (Barstow, Frost, Liben, Ridge, & Souveiney, 1999). In 1996, ESRI produced the first *ArcVoyager* CD, and that same year, the Berkely GeoResearch Group designed and distributed an *ArcView* GIS extension called *Geodesy* for schools. Today, *ArcVoyager*, a free scaled down version of *ArcView* with educational data and lessons, is widely used by schools at all levels and *Geodesy* is used by 86 middle schools across the country (Berkley GeoResearch Group, 2001).

As GIS software has become easier to use, the growth and variety of educational uses has grown exponentially. In 1999, World Resources Institute distributed large amounts of biodiversity and environmental data and published a CD called *DataScape* with ESRI that contains 450 international data layers for students (World Resources Institute, 2001). Today, a variety of easily available data can be downloaded free or for a nominal charge and used by teachers and students who are doing GIS projects in schools.

In 1999, the first GIS Day was held through collaboration between ESRI and the National Geographic Society. The intent of GIS Day is to educate the public and schools about the uses of GIS in their everyday lives. That same year, teachers requested a GIS competition for K-12 schools. Sponsored by ESRI, the annual Community Atlas national competition began. There are 100 Community Atlas GIS projects available with data on ESRI's Website (Environmental Systems Research Institute, 2003b). In 2002, as an outcome of the World Summit on Sustainable Development (WSSD) that was held in Johannesburg, South Africa, an international GIS competition began for secondary schools, colleges and universities called My Community, Our Earth: Geographic Education for Sustainable Development. This competition increases student awareness of worldwide

environmental and social challenges through local, regional, and national sustainable development projects (Environmental Systems Research Institute, 2003c). There are 133 sustainable development projects available on ESRI's Website. These competitions, along with GIS day, have greatly increased the awareness of the importance of understanding and using GIS in schools.

As the school projects and success stories grew, in 2000 the first National Educational GIS conference was held in San Bernadino, California. Every year since 2001, an International GIS in Education conference is held three days before the ESRI Users Conference in San Diego, California. There have been presentations by North Carolina teachers, showcasing their GIS school projects at every GIS in Education user conference in California.

ArcVoyager and *ArcView* by ESRI are not the only GIS software being used by schools. *MapInfo*, Intergraph's *GeoMedia*, *MF Works*, *AutoCAD Map*, and *Map 2000* are others. But, Baker (2002) found that an overwhelming majority of schools use the GIS software implemented in this study, *ArcVoyager* and *ArcView* by ESRI.

STUDENT LEARNING AND GIS

While several projects by middle and high school students using GIS to solve real problems have been described (Alibrandi, 1998; Michelson, 1996; Ramirez & Althouse, 1995), little research has been done on the uses of GIS in the classroom (Keiper, 1999). Audet (1993) investigated behaviors of experts and novices as they solved a problem using GIS. Three problem-solving styles were identified during the research. Weller (1993) introduced water management problems to sixth graders and concluded that while students

were able to formulate hypotheses relating water resources to precipitation with climate and vegetation, the study was thwarted by computer problems. Baker (2002) conducted a study in which eighth grade Earth Science students studied local air quality indicators using GIS. During the two-week treatment, the GIS students showed a modest improvement in their integration of science process skills, particularly data analysis (geographic and mathematical) activities. However, students were unable to make generalized statements or to see trends in the data. GIS did not encourage pattern finding or spatial analysis.

Some examples of GIS school projects include:

- Chelsea, MA. Students used GIS to help with emergency planning.
- Kingston, Ontario. Students used *AutoDesk* software to look at the mechanics of disease transition.
- Barnstable, MA. Students studied watersheds and water quality.
- Detroit, MI. Students addressed community problems such as where to locate childcare facilities, transportation routes for the food bank and redesigning school districts for equity.
- Washington DC. Students conducted field studies in hydrology and geology using GIS.
- Minnesota. Students joined scientists to track wolves (Environmental Systems Research Institute, 2003a).

The list of schools and their study of real world problems continues to grow. Teachers report that student motivation increases when they know they are contributing to GIS projects that can make a difference to their communities (Alibrandi, Beal, Wilson, Thompson, & Hagevik, 2001; Audet & Paris, 1996; Sanders et al., 2001). Three states now have GIS software for use in all of their schools, Utah in November 2002, South Dakota in

July 2002, and Montana in November 2000 (Environmental Systems Research Institute, 2002). While there are many observational reports of GIS improving student learning and motivation, research has not confirmed these findings. In a study done by Abbott (2001), the use of GIS to solve problems in authentic contexts and students' perceptions of competence to solve problems did not change when compared to conventional classroom instruction. More studies need to be conducted to determine the effects of using GIS in schools.

PROFESSIONAL DEVELOPMENT OF TEACHERS USING GIS

Research shows barriers do exist to successful implementation of GIS in classrooms (Sanders et al., 2001). Teachers integrating GIS into their classrooms may need to change their teaching styles from teacher-centered to a more student-centered approach of problem or project based learning. Teachers who integrate GIS into their curriculum have noticed their own shift from a more didactic methods of instruction to a more student-centered inquiry approach (Audet & Paris, 1996; Bednarz, 1999, 2000). It takes time to learn the software, to practice how to use it, and to use inquiry while implementing GIS-based instruction in the classroom (Bednarz, 1999). In addition, there is a need for application expertise and support as teachers continue to integrate GIS and other spatial technologies into their curriculum (Environmental Systems Research Institute, 1997; McWillimas & Rooney, 1997).

Stubbs et al. (1999) identified major future efforts to use GIS in K-12 education as (1) establishing professional development teams for preparing teachers, (2) supporting teachers in data quality and sharing, (3) providing statewide databases for student projects,

and (4) providing leadership and mentoring for new teachers. In addition, educationally based curricular materials need to be developed that allow students to perform spatial analyses and problem solving techniques (Kerski, 2000). Researchers at the First National Conference on the Educational Applications of GIS (Barstow, Gerrard, Kapisovsky, Tinker, & Wojtkiewicz, 1994) and other GIS researchers (Thompson, 1997; Winn, 1997) have recommended the development of projects that create exemplary GIS-based curriculum materials in a range of subject areas and grade levels. The analytical emphasis of GIS differentiates it from other types of information systems and the emphasis on spatial entities and relationships calls for a curriculum in which spatial reasoning skills are emphasized (Johnson, 1996). There is a difference between knowing about and how to do GIS and how and when to apply and solve problems, or learning with GIS versus learning about GIS (Johnson, 1996; Thompson, 1997). Baker (2002) identified that it was critical for teachers not only to be instructed in how to use GIS, but also in the pedagogy of inquiry and problem solving strategies.

In 1999, the first Mapping Our School Site (MOSS)/CITYgreen GIS workshop for teachers was conducted through Sci-Link at North Carolina State University. Dr. Stubbs established SCI-LINK at NC State University in 1988 (Anderson, 1993), linking scientists with teachers with students. Stubbs, Devine, and Taylor have been involved with educator workshops utilizing GIS since 1996, the first of its kind in North Carolina to use spatial environmental data with teachers and non-formal educators (Stubbs, 2003; Stubbs, Devine, & Hagevik, 2002).

Sci-Link, a founding member of the North Carolina GIS Consortium since 1995, links K-12 schools to higher education and community partners. This includes the N.C. Office of Environmental Education, Center for Earth Observation (NCSU), N.C. Department of Environment and Natural Resources, N.C. Center for Geographic Information Analysis, and the U.S. Environmental Protection Agency. Teachers from this workshop reported success with the curriculum and also added comments and suggestions. From this two-year evolution, an online inquiry-based curriculum using GIS was published that supports student driven inquiry and offers one possible solution to the lack of curriculum for teachers incorporating new technologies such as GIS (Hagevik, 1999).

As a result of grant funding from the Math, Science, and Education Network (MSEN) of North Carolina, the MOSS/CITYgreen GIS workshop was revised based on a model of professional development that incorporates a sociocultural or social constructivist perspective of professional development (Howe & Stubbs, 2003a). The focus of the workshop was to improve science teacher's knowledge, their teaching of science, and to empower them as individuals to implement the MOSS/CITYgreen GIS curriculum in their schools. In a previous study done by Howe and Stubbs (1998), Sci-Link teachers cited an increase in the use of new scientific findings in their teaching, an increase in the sharing of ideas and materials with other teachers, increase in participation in professional meetings and activities, renewed enthusiasm for teaching, and a new sense of their own value and power (p. 167). Based on this model of continuous development and change, the workshop included inquiry by generating questions, designing, conducting field studies, communicating findings, laboratory-based investigations, scientists as experts, and

development of an implementation plan. A follow-up session was held to reflect on their experiences, share successes and mishaps, gain additional new information, and establish an electronic community of support.

The second MOSS/CITYgreen GIS workshop was held in the summer of 2001 with a fall follow-up session (Appendix Q). Continued teacher support was provided for the 2001-2002 school year through online communications and school visits. The concerns noted by Bednarz (1999) were addressed and participants were given time to discuss pedagogy, participate in local field-based experiences, and attend open evening lab times for additional practice. Ongoing training, support and technical assistance were provided. The teachers also received the software and supplies needed to complete the unit in their schools. As a result, three teachers who had implemented the MOSS/CITYgreen GIS curriculum in their classrooms during the 2001-2002 school year volunteered to be a part of the 2002-2003 student research in order to study the student learning that occurred as a result of the curriculum.

MOSS Curriculum Pilot Studies

As the result of an emphasis on integration, an elective course was written and piloted for Wake County Public Schools, NC, that used GIS technologies to teach science and mathematics using real-world data and problems (Hagevik & Thompson, 1998). An integration of science and technology, the course focused on inquiry and problem-based learning (Swartz, 1996). As a result of the success of this elective course, an environmental, inquiry-based, six-week unit was developed and piloted. The curriculum was eventually placed online (Appendix A) and expanded to include pedagogy,

environmental content, GIS instructions, and examples. Some students learned the process faster and understood it better than others. The visual presentation and spatial component of the curriculum seemed to appeal to them. In addition, seventy-five undergraduate and graduate GIS students used the online MOSS curriculum as a final project in their Introduction to GIS course at North Carolina State University (Devine, 2003). They further developed the problem solving inquiry-based curriculum and content, and added GIS instructions to the online curriculum. The college students also piloted the Spatial Experience Survey (SES) and the Learning Styles Inventory (LSI) and changes were made to the instruments based on the results of the study.

The online MOSS curriculum has led to a number of associated MOSS projects and has expanded to formal and non-formal settings (Stubbs, 2003). Some examples include an interactive online web-based worldwide project called GIS Live, held in the fall using the MOSS curriculum (GISLive, 2002). The MOSS curriculum has been used by teachers and students and modified to focus on other animals such as in one school where students studied the nematodes in the soil. In addition, in a North Carolina high school, a water quality study was added on their campus that included a pond, grassy area, and a tree stand. The students recorded their data, mapped it, and provided a detailed assessment of their plot. The data was stored for future classes as an archive with which to make future informed decisions. The students enjoyed being involved in a real-world problem. “It gave them the opportunity to apply their knowledge and skills to something tangible. They got an idea of what it is like to conduct scientific research in the field. They had to analyze and

synthesize the data. They knew that the entire class was depending on the quality of their work" reported DeeDee Whitaker, a high school teacher (Stubbs, 2003).

CITYgreen GIS Curriculum

CITYgreen (American Forests, 2000b), an extension to ArcView, is being used by more than two hundred cities as a powerful GIS application for land-use planning and policy-making. The software statistically analyzes the ecosystem services of trees and vegetation to calculate the dollar benefits based on site conditions. Engineers and planners can then model development scenarios, evaluate landscape ordinances, and calculate storm water management costs. Foresters use the program to plan maintenance, planting, and preservation of trees. Educators use CITYgreen to teach forestry, environmental studies, planning, and landscape architecture.

Middle and high school teachers and students in Rhode Island, North Carolina, and Maryland have used Citygreen, GIS, and aerial photographs of their schools to create an ecological analysis of their schools based on trees and tree canopy cover (Harte, 2002). For example in Rhode Island, the *One, Two, Tree* inventory is an interdisciplinary project that merges geography, natural science, and environmental studies with GIS to address a significant community issue—the protection and preservation of community forests. This project has expanded to include 500 students and 10 communities (English & Feaster, 2003).

CITYgreen GIS Curriculum Pilot Study

Citygreen involves students in collecting data on trees, buildings, impervious surfaces, grasslands, bare ground, air conditioners, and shrubs on their school campuses.

GIS formulates statistics on the site and reports carbon sequestration and storage, pollution removal benefits, energy conservation, and tree growth models. Informed decisions can then be made regarding the management of the outside environment. Teachers who have used CITYgreen GIS in their classrooms have said:

- "It is as important for us to manage our green environment as our building environment. We are planning a nature trail through our school campus. We have received grant money to plant trees removed due to building renovations." (Ginny Owens, Ligon GT Middle School, Raleigh, NC)
- "We can do tree-loss counts resulting from the construction on our campus." (Sarah Hannawald, Greensboro Day School, Greensboro, NC)
- "My students have learned how to collect data, make observations, formulate hypothesis, solve problems, and ask questions." (Pat Schweigert, Leesville Middle School, Raleigh, NC)
- "My students have studied the impact of human development and the consequences of population density." (Val Vickers, Greensboro Day School, Greensboro, NC)
- "Using GIS has showed me how to take science outside and relate it to the local environment. It has shown me how to integrate technology into the science curriculum in a new and better way." (Carolyn Moser, Leesville Middle School, Raleigh, NC).

Students are using increasingly sophisticated techniques to explore their local environment and their role in shaping its future (Harte, 2002). We are at the beginning of an explosion and expansion of the use of environmental data to help us solve the problems of humankind. It is important that all students learn how to use technology in their everyday lives and to be technologically prepared for the jobs of the future. MOSS, CITYgreen and GIS methodology integrates science, mathematics, and the newest technologies (GPS,

remote sensing and wireless hand-held devices) that will aide in preparing educators and students for the challenges of the future (Stubbs, 2003).

Despite these claims, very little research has been done on the use of GIS in the classroom. In this study, CITYgreen GIS, a school campus analysis that uses predetermined models, was compared to the MOSS curriculum, a 10m x 10m quadrant study, in which students created their own experiments and draw their own conclusions.

OTHER CONSIDERATIONS

TEACHING USING TECHNOLOGY

Technology is a social and technical process, which involves the application of knowledge, tools, and skills to solve practical problems and extend human capabilities (Johnson, 1989). Society has embraced and used computer technology to reinvent the ways in which we create, find, exchange and think about information (Pierson, 2001). In the past decades, the implementation of technology in America's classrooms has been a major focus of several educational reforms and policies (U.S. Department of Education, 2000). Since the development of the nation's first educational technology plan in 1996, American schools have noticed a significant emphasis on the use of technology as an instructional tool in classrooms (Office of Educational Technology, 1999).

Educators, parents, and governmental officials are challenged with offering students the technological skills needed to become successful citizens (U.S. Department of Education, 2000). Educators find themselves faced with addressing these issues, as they teach students how to apply technologies to core subjects such as reading, mathematics, and

science (Reid, 2003). In fact, it has been argued that integrating technology tools into the curriculum has become an inseparable part of good teaching (Pierson, 2001). Through student investigations, educators can offer students the opportunity to appreciate the important role of technology in the formulation of scientific concepts as well as social and economic issues (Reid, 2003). Therefore, it is imperative that science educators provide students with a variety of experiences that highlight the advances of technological tools (Rakow, 1998).

In a study done by Reid (2003), middle school students were able to use technologies provided to improve the quality of their scientific investigations. The technologies enhanced the students' learning of scientific concepts by providing opportunities for them to collect high quality data. Pierson (2001) reported that teachers who were experienced at using computers for instruction shared teaching practices such as planning for regular computer use and consistently using technology as a tool in a variety of instructional projects. They maintained higher expectations for student learning, and were willing to shift focus toward activities that were student centered with less whole group instruction and more independent work (Evans-Andris, 1995). Literature on exemplary technology-using teachers characterizes them as using more student-centered learning, viewing computers in terms of function rather than application, and using more complex project-based activities in their classrooms (Becker, 1994; Hadley & Sheingold, 1993).

Reid (2003) noted that our society does not need teachers who merely know how to use computers. Instead, we need exemplary teachers who know how to effectively use all the tools at their disposal for the learning benefit of all students. Technology in the hands

of a merely adequate teacher will not provide the experience and thoughtful motivation necessary to embed the technology within the context of sound teaching and conversely, technology in the hands of an exemplary teacher will not necessarily result in integration and meaningful use. Pierson (2001) found that unless a teacher views technology as an integral part of learning, it will remain peripheral to his or her teaching. Expert teachers who are described as having pedagogical-content knowledge or knowledge of specific learners and curriculum may also need another component, technological knowledge (Pierson, 2001). Educational leaders need to look beyond technology purchases and focus efforts instead on creating environments that are conducive to continued growth in pedagogy as well as in technology use. The MOSS/CITYgreen GIS workshops and follow-up teacher support are a step toward creating such environments that support the full integration of technology into classroom practice to improve student learning (Stubbs, 2003; Stubbs et al., 2002).

Grounded Research Theory

Olsen (2000) used spatial analysis tools and GIS with ninth and tenth grade Biology students to select a site for a prairie restoration project on a 55 acre campus during a four-week environmental unit. The interpretations of the learners' socially constructed actions and their iterative building of assertions came from multiple sources and were analyzed using grounded theory techniques. Olsen's analysis of verbal and nonverbal behavior, communication within and across cultural groups and conversational analyses showed that students' meaning-making actions were not mediated by GIS tools and that students did not see themselves as participants in the environmental problem-solving community. The

students did gain proficiencies in using GIS tools at an operational level, but they did not view themselves as practitioners.

Audet (1993) investigated the behaviors of experts and novices to expand the knowledge base regarding how students interact with ArcView GIS to solve problems. The respondents were audio taped during 'think aloud' sessions and expert, novice, and transitional problem-solving styles were identified using thematic components and naturalistic techniques. Grounded theory is not generated deductively but rather inductively from the study of the phenomenon represented. One does not begin with a theory and then prove it, but alternatively, one begins with an area of study allowing what is relevant to emerge (Strauss & Corbin, 1990). The grounded approach advocates the use of multiple data sources (Glaser & Strauss, 1967). Quantitative data can indicate directly observable relationships and corroborate the findings from qualitative data while qualitative data improves understanding of underlying relationships in the data. The use of multiple data sources enhances construct validity and reliability (Pandit, 1996).

ATLAS.ti (Scientific Software Developments, 2003) is a powerful software program for qualitative analysis of large amounts of textual, graphical, and audio data. The two modes of data analysis are textual, which focuses on the raw data including text segmentation, coding and memo writing and conceptual, which focuses on framework building including the interrelating of codes, concepts, and categories in order to form theoretical networks. Atlas.ti offers tools to manage, extract, compare, explore, and reassemble meaningful pieces of extensive amounts of data in creative, flexible and systematic ways (Muhr, 1997). This study applies the systematic and rigorous application

of the grounded theory method to understand the underlying relationships in the data and to corroborate findings revealed by the quantitative data.

Video Analysis

Videotaping students' interactions provides a means of identifying how students use thinking skills, appropriate tools, and strategies to solve problems (Maor, 2000). An inquiry-based learning environment is well supported by the use of interactive technologies, such as GIS, which promotes small group work and interactions among students (Maor, 1999). In a constructivist-oriented, inquiry-based learning environment, small groups of participants engage in reflection and collaboratively determine a problem, generate creative questions and design investigations in meaningful contexts. In a study done by Maor (2000), videotaping was used to analyze students' higher order thinking skills. Presentations by pairs of students to the whole class informed teachers and other students of the extent to which the participants were successful in using their higher order thinking skills. Results showed that students did progress from lower levels of inquiry skills to higher levels during the study. The digital video analyses of the data made it possible to code and analyze multiple dimensions in the data such as dialogue and researchers comments. Videotaping student interactions in this study provided a means for better understanding the context of the social processes of students' learning. Students' were able to reflect on their experiences, interpret new information, and analyze and make judgments about its relevance, synthesizing what they had learned to generate new knowledge. Teachers and students using GIS engaged in whole group presentations that were

videotaped and analyzed to better understand the extent to which the participants were successful in using GIS to understand environmental content.

SUMMARY

From an inquiry-based, problem-solving, constructivist perspective, as detailed in this review, a deep and thorough understanding of environmental concepts using GIS requires not only an understanding of the technology but also effective ways in which to use that technology (technology-knowledge) in teaching and learning. If this understanding is fully developed, then GIS may hold great promise for teaching science and mathematical concepts, spatial-visual thinking, inquiry and problem solving and important technology skills required for future success. Reform documents such as the *National Science Education Standards*, the *Standards for Technological Literacy*, and the *National Council of Teachers of Mathematics Standards* advocate an increased emphasis on real-world problem solving in which inquiry-based learning and thinking occur, using technology as both a tool and goal of learning. However, the development of a structural understanding on effective implementation is a complex and difficult process hindered by misconceptions and the absence of complete models and research.

Tracing the history of GIS technologies and its infusion into our daily lives, including our classrooms, provides some insight into the complex nature of teaching and learning using GIS and establishes a basis for identifying and addressing strategies and hindrances related to teaching and learning with technology. Literature pertaining to how teachers implemented GIS and ways students understand and experience learning with GIS,

indicates that students rely on previously formed images, intuitions, and experiences. For example, spatial ability and learning preferences may play a role in the learning of science in a technology rich learning environment. An analysis of research results suggests that instruction needs to follow a more constructivist model, in which activities are sequenced, increasingly becoming more complex and diverse. In addition, teachers need training, time, support, and practice when implementing inquiry-based, problem solving instruction with GIS. Exemplary GIS-based materials need to be developed, tested, and evaluated. In particular, three recurrent themes pertaining to teaching and learning with GIS have emerged from the literature: (1) the importance of inquiry-based, problem solving teaching and learning that allows teachers and students to gather, analyze, and interpret real-world data, (2) the importance of activities that emphasize connections and reflection among various types of information, and (3) the importance of spatial ability and visualization in the learning of science.

Results of GIS in education studies, presented in this review, lend further support to these recommendations. Alibrandi (2003) states that GIS in schools is, "authentic community problem solving, when the students "get it," it is truly theirs and the community's. They become reconnected in a way that no isolated content can connect them" (p. 165).

GIS technology has shown promise in engaging students in inquiry-based real world problem solving, connecting them with their communities. Students become excited and motivated as they construct mutual and deeper understandings of their environment. Teaching and learning with GIS has the potential to enhance the teaching and learning

environments in schools, increase spatial data analyses, support interdisciplinary connections and to motivate students. However, technologies like GIS are changing so rapidly that it is difficult for the research community to build an understanding of the impact of technology on student learning. While the majority of the research cited in this review showed a positive impact on data analysis skills and student attitudes and motivation, most of the research relies upon case studies or comparisons between expert and non-expert users, and the majority of research conducted on the impact of learning with GIS focuses on higher education. Clearly, there is a gap in the research and teaching and learning of K-12 students with GIS. Other experimental designs compare non-GIS users using problem-based learning techniques to GIS users. There is a lack of studies that investigate different uses of GIS on teacher and student learning.

Given the increased acceptance and use of technologies such as GIS and GPS in today's science curriculum, the science education community must explore the various aspects of this technology in relation to student conceptual development and learning. With regard to students' understanding of problem-solving using GIS, Baker (2002) states: "GIS can extend students' abilities to conduct location-based scientific research…it is important in the future to study student spatial analysis abilities, the use of GIS to promote inquiry and geographic pattern-seeking activities, and the development of curricula that supports these activities" (p. 122-125). Following this suggestion, this study looked at the effects of learning environmental science concepts with GIS technology in two problem solving inquiry-based curricula. This study correlates teacher and student understanding to spatial

ability and will provide information regarding the impact of real-time GIS mapping and data collection on students' understanding of environmental content.

CHAPTER 3. METHODOLOGY

This study examined middle school students' understandings of the environment and GIS after using two GIS inquiry-based problem-solving units, MOSS and CITYgreen GIS. Pilot studies and a review of the literature led to the development of the following research hypothesis for each of the research questions identified in Chapter 1.

1. Students using the MOSS curriculum will show a significantly better understanding of environmental concepts as measured by quizzes, tests, written conclusions, analysis, lab reports, lab presentations, and interviews as compared to students using the CITYgreen GIS curriculum.

Following the teaching of environmental science with GIS, other factors were investigated such as students' spatial abilities, experiences, and learning preferences. Students who excel at spatially related tasks may be more predisposed to this type of presentation and therefore able to better understand the concepts than those who are not.

2. Students who are visual learners and have more significant predictors on the SES will be more successful on the PSVT:R test and will have a better understanding of GIS as measured by the quiz, unit test, and individual conclusions than those who have low PSVT:R scores.

Finally, since qualified teachers who are confident in teaching with GIS are key to the success of the curricula (Baker, 2002; Stubbs et al., 2002), the effectiveness of the MOSS/CITYgreen GIS workshop was investigated over a two year period.

3. At least half the teachers will demonstrate continued use of GIS in their classrooms for instruction the school year after the year of the MOSS/CITYgreen GIS workshop.

This study used a mixed methods approach, that is, used qualitative and quantitative research methods as supported by the educational research community. Cook and Reichardt (1979) explain that (a) the use of mixed methods provides a mechanism for evaluating the process of the outcomes, (b) each method offers insight that neither could do alone, and (c) the application of both methods in tandem helps to correct biases that are characteristic of each method. Appropriate statistical tests were made to determine differences in students' conceptual understanding of environmental content. Differences in spatial abilities were also analyzed using statistical measures. Student interviews and artifacts were used to further interpret and characterize the findings.

POPULATION AND SETTING

The population of this study consisted of middle and high school teachers and seventh and eighth grade middle school students. The teacher sample consisted of all teachers (n = 12) enrolled in a one-week summer professional development opportunity and fall follow-up session at North Carolina State University in Raleigh, NC. The students were seventh and eighth graders (n=164) in two public middle schools, one located in Raleigh, Wake County and one in Durham, Durham County.

Ninety-six of the students were from Leesville Middle School in the city of Raleigh, Wake County. Wake County, located in the Piedmont region of North Carolina, has an

estimated population of 702,000 residents. The rapidly growing Wake County Public School system currently has a student population consisting of 105,000 students in 125 schools, including 79 elementary, 25 middle, 16 high, and five special/optional schools. Wake County Public Schools students are 61.6% white, 26.3% African-American, 5.6% Hispanic, 4.1% Asian, 2.1% multiracial, and 0.3 % American Indian.

The middle school is one of three schools in the Leesville Road complex, located between an elementary and a high school. The student population of 1,000 students includes 34% white, 14% black, 31% Asian, 10% Hispanic, and 11% Other. The percentage of students on free or reduced lunch is 15%. Leesville Middle School is a North Carolina School of Excellence, with students meeting the established high growth standards in academic gains during the 2001-2002 school year (Wake County Public School System, 2003). The school operates on a traditional ten-month school calendar and provides a core curriculum of science, math, language arts, and social studies to all students. In addition, students take elective classes in physical education and the performing arts.

Sixty-eight students were from Carrington Middle School, in the city of Durham, Durham County. Durham County, adjacent and west of Wake County in North Carolina, has an estimated population of 223,314 residents. Durham Public Schools' growing student population consists of 27,000 students in 42 schools, including 27 elementary, nine middle, and six high schools. The student population consists of 42.4% white, 43.5% African-American, 3.6% Hispanic, 8.6%, Asian, and 1.9% Other.

The Carrington Middle School student population of 1,235 students is 44% white, 47% black, 4% Hispanic, and 5% Other. The percentage of students on free or reduced

lunch is 26.90% (North Carolina Department of Public Instruction, 2003). Carrington Middle School is also a North Carolina School of Excellence, with students meeting the high growth standards in academic gains during the 2001-2002 school year (Durham County Schools, 2003). The school operates on a traditional 10-month school calendar and provides a core curriculum of science, math, language arts, and social studies to all students. In addition, students take elective classes in physical education, performing arts, and career discovery.

The twelve workshop teachers were from nine different schools in Wake, Guilford, Cumberland, Chapel-Hill/Carrboro, and Durham counties. The middle and high school teachers in the program were 75% female and 25% male. Their teaching experience included three teachers with 7 to 12 years of experience, three teachers with 13 to 18 years of experience, three teachers with 19 to 25 years of experience and three teachers with 26+ years of experience. School support of supplies and technical assistance for this professional activity was reported by teachers as small with only one school, Ligon GT Middle School in Wake County, reporting great support. Teachers in the program were active in other professional development activities in the last 12 months, six had taught other in-service programs, eight attended national and state or regional meetings, six served on curriculum committees, and 10 had attended a workshop. One participant had a Ph.D., one was a Ph.D. student, and four others held Master's degrees, resulting in half the teachers in the workshop holding advanced degrees.

DESIGN AND PROCEDURES

The twelve teachers self-selected and became part of a professional development opportunity at North Carolina State University in the summer of 2001 where they learned how to teach two inquiry-based problem solving science units of study using GIS, MOSS and CITYgreen GIS. Teachers involved in the program received all of the necessary software (valued at $1,000), a stipend, and science equipment to use when implementing the project. An Eisenhower Grant from the statewide Mathematics, Science, Education Network supported the workshop. Additional support included one fall follow-up meeting, e-mail support and school visits the following school year (2001 - 2002).

Three teachers from the summer workshop agreed to participate in the student study the following school year, 2002 - 2003. Two female teachers, a media specialist and a science teacher, worked together and taught the MOSS unit to five basic science classes at Leesville Middle School. One male elective teacher at Carrington Middle School taught three biotechnology classes using the MOSS curriculum in the fall. He also taught four different biotechnology classes using the CITYgreen GIS curriculum in the spring. All three teachers were experienced, certified teachers who had been at their schools for over ten years. The teachers each had 27 years of teaching experience and the media specialist at Leesville Middle School had 11 years of teaching experience. In an effort to control for instructor differences, the instructors adhered to the same schedule of activities (Appendix Q). In addition, all the instructors used the same class assignments and unit quizzes, test, and final project. The classes were observed on a weekly basis, and the researcher provided additional support during the school year by answering questions, reviewing activities,

providing technical support, and collaborating on lesson plans. All students in the study completed the online Learning Styles Inventory (LSI), Spatial Experience Survey (SES), and Purdue Spatial Visualization Test: Rotations (PSVT:R), before beginning the GIS units. These scores were used to measure spatial ability.

EXPERIMENTAL AND COMPARISON GROUP

All class periods were 50 minutes in length and were held every day. The MOSS and CITYgreen GIS units were each taught over a six-week period. Necessary software had been previously installed at the schools in the computer laboratories. All teachers had taught the curriculum the previous school year before beginning the study. In the fall, all of the teachers and students used the web-based online MOSS curriculum (www.ncsu.edu/scilink/studysite) to complete the unit. The comparison group at Carrington Middle School used the CITYgreen GIS curriculum in the spring. The student sample was not random (experimental: $n = 131$, comparison: $n = 33$) leading to a nonequivalent comparison group design for this study. The variables were (a) differences on the MOSS and CITYgreen quiz, (b) differences on the MOSS/CITYgreen test, (c) differences in the final lab report, (d) differences in the final individual written conclusions, (e) and differences in the analyses done by the students. Table 4 summarizes the school and student assignments.

Table 4: School and Student Assignments

School	Semester	Time	Group	Number of Students
Carrington	Fall 2002	8:00 - 8:50	Experimental	17
	Fall 2002	9:50 - 10:40	Experimental	11
	Fall 2002	10:45 - 11:35	Experimental	7
Leesville	Fall 2002	8:35 - 9:25	Experimental	17
	Fall 2002	9:30 - 10:20	Experimental	22
	Fall 2002	10:25 - 11:15	Experimental	15
	Fall 2002	12:10 - 1:05	Experimental	18
	Fall 2002	2:10 - 3:05 PM	Experimental	24
Carrington	Spring 2003	8:00 - 8:50	Comparison	3
	Spring 2003	8:55 - 9:45	Comparison	8
	Spring 2003	9:50 - 10:40	Comparison	12
	Spring 2003	10:45 - 11:35	Comparison	10

DEVELOPMENT OF THE INQUIRY-BASED PROBLEM SOLVING GIS CURRICULA

The treatment used in this study was the teaching of an inquiry-based problem-solving unit using GIS (MOSS) for a six-week period of instructional time. MOSS, an online curriculum, also demonstrates how teachers can use a Web site for instruction. It requires equipment for data collection, a variety of field guides for plant and animal identification, computers with at least 32 MB of RAM and a Pentium processor, and the GIS software, *ArcView* (1996) by Environmental Systems Research Institute (ESRI). The comparison group used an extension to *ArcView,* CITYgreen, by American Forests (2000a). Both the MOSS and CITYgreen GIS units were designed over a three-year period and have

been tested by hundreds of students in classrooms across North Carolina (Stubbs et al., 2002). The timeline of the development and implementation of these units is explained in Table 5.

Table 5: Timeline of Implementation of MOSS and CITYgreen GIS Units

Year(s)	Implementation Steps
1997 - 1999	Beginnings of MOSS unit at Ligon Middle School. GIS Elective Course called Computers, Satellites and Mapping designed and taught in Wake County Public Schools.
Summer 2000	First MOSS teacher workshop held. Beginning of online MOSS curriculum.
2000-2001	Pilot CITYgreen GIS project at Ligon Middle School. Pilot MOSS project with 75 undergraduate and graduate students. Continued online curriculum development.
2001-2002	MOSS/CITYgreen GIS teacher workshop for research study. Fall follow-up meeting. Mentoring of teachers during school year.
Summer 2002	MOSS/CITYgreen GIS teacher workshop.
Fall 2002	MOSS research at Leesville Middle and Carrington Middle Schools. GIS Live online conference using MOSS. Informal education programs begin using MOSS.
Spring 2003	CITYgreen GIS comparison group at Carrington Middle School.
Summer 2003	MOSS/CITYgreen GIS teacher workshop. Informal education summer programs use MOSS and CITYgreen GIS.

Table 2, in Chapter 2, shows the relationship between the recommendations of Swartz (1994) and Bonnstetter (1998), which formed the conceptual framework for this study. Students applied the steps of skillful problem solving by Swartz (1994) as they used inquiry (Bonnstetter, 1998) to solve environmental problems. In the MOSS curriculum,

students choose a 10m by 10m study site to investigate the relationships between the abiotic and biotic components of the environment using GIS. The developer recommends a site be chosen that has a variety of vegetation and, if possible, a water source. Students then measure, survey, and stake out the site. Teachers spatially orient the students by providing them with a data collection grid. Students must use a compass to locate north at the top of the grid. All points on the grid, data table, and associated attribute data are located by their x, y coordinates as shown in Figure 3. The grid is not georeferenced to real world coordinates. However, it is possible to later georeference the grid to an aerial photograph of the school.

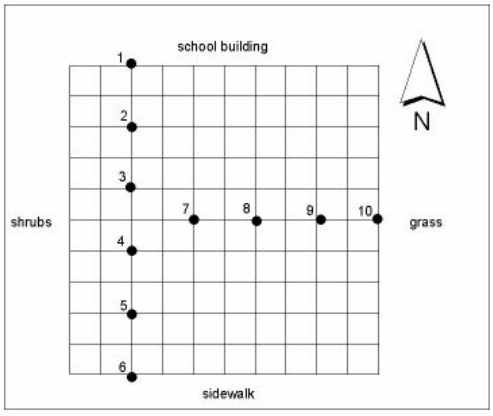


Figure 3: Grid With Pitfall Trap Locations

The five procedures outlined on the MOSS Web site are initially conducted, and then, using a spreadsheet program like EXCEL© (Microsoft Corporation, 2003), are stored in digital form on the computer. Using an *ArcView* procedure called "add event theme" the data are displayed on the grid as points. The vegetation points are digitized to create themes. Students then use *ArcView* to analyze patterns in the data and the study site. As patterns reveal themselves, students develop problem questions and student research groups

are formed according to their interests (Hagevik, 2003b). Students become active and engaged as they develop their problem questions, collect their materials, design their data tables, and conduct additional procedures to help answer their problem question. The students then use any of the available data from the first five procedures in addition to their own procedure to analyze the data spatially and draw conclusions, creating a map to communicate their conclusions to others.

Students in the comparison group also engage in inquiry by using an extension to *ArcView* to create an ecological analysis of their school site based on trees. CITYgreen (American Forests, 2000a) involves students collecting data on a portion of their campus (trees, buildings, sidewalks and pavement, grass, and shrubs). This GIS extension then formulates statistics on the school site and reports the carbon sequestration and storage, pollution removal benefits, energy conservation, and tree growth based on pre-programmed formulas using the trees on the school site. Teachers and students discuss the results, formulate additional problem questions, and run the corresponding environmental management scenarios with the computer program. Finally, they report their findings and maps to the class.

Both the comparison and experimental groups collected similar data about their school campuses, used GIS to analyze patterns, formulate problems, and report results. However in CITYgreen GIS comparison group, the teacher selected the topic of study and the program calculated all the results. Students in the comparison group did not design their own data tables, determine their own materials, nor formulate techniques for data analysis as is done in the MOSS curriculum. MOSS and CITYgreen GIS both use inquiry

learning as described by Bonnstetter (1998), however, MOSS represents open inquiry in which the students choose their own problem questions and design their own investigations. CITYgreen GIS represents guided inquiry where the teacher chooses the topic, the question, and provides the necessary materials required to complete the investigation.

DEVELOPMENT OF THE CURRICULA AND INQUIRY -BASED LEARNING

Bonnstetter describes traditional "hands-on science" as when the teacher directs the decision-making from topic to conclusion. Crawford (2000) sees many traditional teachers as providing a series of hands-on activities that are often unconnected to each other or to substantive science content. The role of the teacher in traditional science education is the giver of knowledge with students as knowledge receivers, regardless of whether equipment is used. This contrasts to inquiry-based learning where teachers lead students to revisit their understandings, building on students' experiences. In an inquiry classroom, the students identify and solve problems, explore and manipulate materials, collect data, ask questions, engage in discussion, and invent and explore concepts while the teacher organizes the experience, provides materials, asks leading questions, monitors progress, and explores and invents concepts with the students (Westbrook & Rogers, 1994). Crawford (2000) outlines six characteristics of an inquiry lesson:

1. Instruction is situated in authentic problems
2. Focus is on the grappling of data
3. There is collaboration of students and teacher
4. Connections with society are developed
5. The teacher models the behavior of a scientist
6. There is an increasing development of student ownership (p. 922)

Bonnstetter (1998) further explains that as the process moves from traditional to student research, the learning becomes more student controlled, focused on learning, and results in endogenous change or the internal reconstruction of new information as measured by creativity and solving problems in new situations. The MOSS and CITYgreen GIS units involve the following four levels of inquiry 1) Structured, 2) Guided, 3) Student Directed, and 4) Student Research:

Structured Inquiry

Structured inquiry requires students to reach their own conclusions based on supportive evidence but the activity, chosen by the teacher, is highly structured. In the MOSS curriculum (Hagevik, 1999), structured inquiry was used only when introducing basic skills needed to complete the experiments such as measuring, pacing, or using a clinometer. The comparison group in this study participated in a comparative GIS curriculum that required an extension to GIS called CITYgreen (American Forests, 2000a). Once again, structured inquiry was used only to teach the students basic science skills such as measuring, using a clinometer, measuring the diameter and canopy radius of trees, and identifying trees using a field guide.

Guided Inquiry

During guided inquiry, the teacher selects the topic, the question, and provides the necessary materials required to complete the investigation. However, the teacher and the students design the investigation, analyze the results, and reach logical conclusions. The MOSS curriculum uses guided inquiry to help teachers and students learn the steps of skillful problem solving and the process of GIS analysis. The first five procedures, trees,

abiotic, pitfall traps, animals, and vegetation cover, provide a topic of study, materials, and an outline of procedures, but the teacher and students must develop many additional procedural questions. For example when collecting tree data, the students must determine criteria to differentiate between a tree and a shrub or when identifying animals in the 10m by 10m study site, the students must decide what to do when an animal flies in and out of the area.

The comparison group used the CITYgreen GIS curriculum, which also relies on guided inquiry. Data are collected using predetermined procedures and entered into templates on the computer. Teachers and students do make some decisions, such as what data to collect, how to determine the crown size of trees, or which trees to include in the campus study site. The computer calculates, using formulas, the benefits of trees to the school, producing a report. The students then discuss the results, draw conclusions, construct additional queries, and present their results.

Student Directed Inquiry

In student directed inquiry, although the teacher may assign the general topic of study, students take responsibility for every part of the process. This includes the development of their own research questions, organization of materials, procedural design, results, analysis, and conclusions. The teacher may guide the students' question development. In the MOSS curriculum, student research groups used GIS to search for patterns and relationships from the data they collected previously. Each group designed their own problem question, collected necessary materials, determined the procedure including their data collection table, and analyzed the results using GIS to report

conclusions in the form of a written report and map. The teacher chooses the general topic; what are the relationships between the biotic and abiotic components of a 10m by 10m study site?

In contrast, the comparison CITYgreen GIS group did not participate in guided inquiry because the software developers predetermined the materials, procedures, and the mathematical calculations. However, the results did require interpretation by the teacher and students in order to formulate conclusions.

Student Research

The highest level of inquiry is called student research. Here, the student is responsible for every part of the process with little more than guidance and support from the teacher. Not all students will engage at this level but teachers should be ready to support any students who have the interest, drive, and ability to pursue this goal. The MOSS curriculum allows for motivated students to develop their own experiments with the guidance of the teacher. In contrast, the CITYgreen GIS group did not participate in student research because the materials, procedures, and mathematical calculations were predetermined.

Both the CITYgreen GIS and MOSS groups illustrate Crawford's (2000) six characteristics of an inquiry lesson as shown in Table 6.

Table 6: Six Characteristics of the MOSS and CITYgreen GIS Inquiry Curriculum

Characteristics	MOSS group	CITYgreen group
(1) instruction is situated in authentic problems	What is the relationship between the biotic and abiotic components of the environment?	What are the benefits of the trees on our campus?
(2) a focus on the grappling of data	Abiotic, animals, pitfall traps, trees, vegetation cover, your choice	Trees, air conditioners, bare ground, shrubs, grasslands, impervious surfaces, buildings, water
(3) collaboration of students and teacher	Student groups engage in student directed inquiry or student research	Teachers and students engage in guided inquiry step only
(4) connections with society	Impact of human activities on the environment	The importance of trees and their connection to air quality, water quality, and energy conservation
(5) teacher modeling behavior of a scientist	Students perform steps of scientific problem solving	Students solve problems based on evidence generated by predetermined models
(6) development of student ownership	Collaboration of conceptual learning through shared experiences	Collaboration of conceptual learning through shared experiences

The main difference between the MOSS and the CITYgreen GIS curriculum is the role of the teacher and student. The MOSS inquiry unit is more student-centered. The teacher guides students as they choose their own research question, design a procedure and data table, select needed materials and collect the data, and then analyze their results using GIS. Students direct their own learning. As a result, the learning climate of the classroom oftentimes changes (Bonnstetter, 2000) from a direct approach in which there is a right or wrong answer to a more open approach in which teachers and students work together to solve authentic problems that may have many possible answers. As compared to the CITYgreen GIS unit in which the teacher chooses the topic and the methods, procedures, materials and analyses are predetermined.

DEVELOPMENT OF INSTRUMENTS

For the entire study in order to investigate the three research questions, several instruments were developed. Instruments used in this study include the MOSS quiz, the CITYgreen GIS quiz, the MOSS/CITYgreen test, a written conclusion, a GIS analysis and project, group lab reports and presentations, a teacher GIS Users questionnaire, and interview guides for teachers and students, a Spatial Experience Survey (SES) for adults and students, a Learning Styles Inventory (LSI), and the Purdue Spatial Visualization Test: Rotations (PSVT:R).

An objective MOSS quiz (Appendix E), a CITYgreen GIS quiz (Appendix F), and a MOSS/CITYgreen test (Appendix G) measured students' understandings of the environment and GIS. The GIS learning objectives were developed from the guidelines set forth by the University Consortium for Geographic Information Science (1996). A quiz and test assessed common content and GIS concepts used by the students as shown in Tables 7-10.

Table 7 shows the learning objectives covered by the MOSS quiz and the CITYgreen GIS quiz. Only the common content shared by the MOSS and CITYgreen GIS curricula were tested on the MOSS/CITYgreen test (center column of Table 7) taken by all the students at the end of the units.

Table 7: MOSS and CITYgreen GIS Learning Objectives

MOSS Quiz	***MOSS/CITYgreen Test***	***CITYgreen GIS Quiz***
What are **pitfall traps** and how do they work?	Databases; field names, columns and rows	How were the **trees and shrubs** identified and what measurements were used to determine their size?
What does **abiotic** mean and what were the abiotic components measured in the experiment?	Points, lines, polygons	What is **roof albedo** and how is it related to **buildings**?
How are **animals** identified and used to study the 10m x 10m study site?	What is GIS?	How was **energy conservation** determined?
What is **vegetation cover** and how is it important to the experiment?	What does GIS do for you?	What is the relationship between carbon and **global warming?**
How big is the study site and why is that important to the experiment?	How does GIS work?	How do **wildlife benefit** from trees?
How did you identify the **trees** and what measurements were used to determine their size?	Data analysis	What are **impervious surfaces** and how is it related to water run-off?
What is GIS and how is it used?	Modeling	What is the size of the study site?
	Asking problem questions	What is GIS and how is it used?
	Field guides	
	Relationship of abiotic and biotic components	
	Trees; DBH, clinometer, tree height, tree type, benefit of trees	
	Vegetation cover; grasslands, shrubs, bare ground	

Tables 8-10 show how the conceptual framework (Table 2, Chapter 2) was incorporated into the assessment instruments. The quiz and test items measured how well the students understood the inquiry process, environmental content, and GIS.

The MOSS quiz was designed by considering the content in Table 7 and then measuring them through matching items as content objectives shown in Table 8. In addition, the quiz items incorporated the process objectives by asking questions related to

each of the steps of inquiry (Bonnstetter, 1998), shown as process objectives in Table 8. The quiz questions were on the five procedures of trees, abiotic, animals, pitfall traps, vegetation cover, and on the definition of the study site. Students at the time of the quiz had collected data on these five procedures and with GIS had identified patterns so that they could begin to formulate their own problem questions.

Table 8: MOSS Quiz Environmental, Process, and GIS Learning Objectives

Quiz Items **Environmental Content**	***Process Objectives*** **Inquiry-based learning**	***Content Objectives***
1, 2, 4,10, 15, 17, 22	Research Topic	Animals, vegetation, abiotic, pitfall, trees
7, 20	Student Research Questions	Animals, vegetation, abiotic, pitfall, trees
2, 5, 9, 11, 18	Materials	Animals, vegetation, abiotic, pitfall, trees
3, 4, 6, 9, 16, 18	Procedure/Design	Animals, vegetation, abiotic, pitfall, trees and study site
12, 14, 20	Result/Analysis	Patterns and evidences
Short answer on problem questions and ways to solve them	Conclusion (Bonnstetter, 1998)	Problem question and a way to solve it
GIS Content	**GIS and Problem solving**	
8, 13, 14, 17, 18, 19, 21	Step 1 - planning, Step 2 - spatial database, Step 3 - attribute database, Step 4 -Data Analysis, Step 5 - Conclusion (Chen, 1997)	Planning, attribute data base, spatial database

The CITYgreen GIS quiz was designed by considering the content in Table 7 and then measuring them through matching items as content objectives shown in Table 9. The CITYgreen GIS students had collected and used the CITYgreen GIS extension to enter the data into the computer. The data these students collected was on trees, buildings, shrubs, impervious surfaces, and buildings on their school campuses. In addition, the quiz items incorporated process objectives by asking questions related to each of the steps of inquiry (Bonnstetter, 1998), as shown in Table 9.

Table 9: CITYgreen GIS Quiz Environmental, Process, and GIS Learning Objectives

Quiz Items **Environmental Content**	***Process Objectives*** **Inquiry-based learning**	***Content Objectives***
1, 2, 10, 15, 18, 22	Research Topic	Buildings, trees, impervious surfaces, shrubs
7, 14, 20	Student Research Question	Trees, animals, environment
9, 11	Materials	Study site, trees
4, 6, 9, 16, 17, 18	Procedure/Design	Trees, study site
3, 5, 12, 14, 20	Result/Analysis	Energy conservation, tree canopy, wildlife benefits, global warming
Short answer on problem questions and ways to solve them	Conclusion (Bonnstetter, 1998)	Problem question and a way to solve it
GIS Content	**GIS and Problem solving**	
8, 11, 12, 13, 14, 17, 19, 21	Step 1 - planning, Step 2 - spatial database, Step 3 - attribute database, Step 4 -Data Analysis, Step 5 - Conclusion (Chen, 1997)	Planning, attribute data base, spatial database, data analysis

The MOSS/CITYgreen Test was designed by considering the content in Table 7 and then measuring them through multiple choice items as content objectives shown in Table 10. The unit test measured common objectives between the two curricula. Since the MOSS/CITYgreen test was taken at the end of the units, it was much broader in scope and for example, included items related to environmental health, modeling, and data analysis.

Table 10: MOSS/CITYgreen Test on Environmental, Process, and GIS Learning Objectives

Test Items **Environmental Content**	***Process Objectives*** **Inquiry-based learning**	***Content Objectives***
5, 6, 12,13, 14	Research Topic	Trees, study site, animals
6, 16	Student Research Questions	Study site, problem questions
13	Materials	Trees, animals, shrubs
4, 6, 7	Procedure/Design	Data tables, study site
3, 5, 11, 15,16, 20, 22	Result/Analysis	Trees, data analysis, modeling, health, answering problems, shrubs, vegetation cover
Short answer on problem questions and ways to solve them	Conclusion (Bonnstetter, 1998)	Problem question and a way to solve it
GIS Content	**GIS and Problem solving**	
1, 2, 3, 4, 7, 8, 9, 10, 17, 18, 19, 20, 21, 22	Step 1 - planning, Step 2 - spatial database, Step 3 - attribute database, Step 4 -Data Analysis, Step 5 - Conclusion (Chen, 1997)	Planning, attribute data base, spatial database, data analysis, conclusion

In addition, after the unit test, each student was asked to write a concluding paragraph to his or her experiment using a prompt (Appendix N). The prompt was developed from the lab report guideline (Appendix O). Teachers who had previously used MOSS and CITYgreen GIS in their classrooms designed the lab report guideline. The conclusion paragraphs can then be compared between the MOSS and CITYgreen GIS groups.

Student groups presented their projects and, guided by the lab report guidelines, submitted a final written lab report and GIS project (Appendix O). Students' lab reports included a procedure log of the GIS analysis steps used to answer their problem questions. Student presentations were videotaped and transcribed. A grading rubric (Appendix O) was developed to score the lab reports, analyses, and conclusions. The grading rubric was

adapted from the KanCRN (2003) Secondary Experimental Research Assessment rubric for scoring student research.

Teacher and student interviews provided data on the nature and extent of their understanding of environmental content and GIS, providing insight into the quantitative part of the study. In order to guide the discussion, a set of questions was prepared in the form of an interview guide. The student interview guide (Appendix L) includes follow-up questions to the MOSS/CITYgreen unit test to explore student misconceptions when using GIS to solve problems. Students are asked to reflect on environmental content and GIS items that they did not understand in order to gain a deeper understanding into the students' perspectives. The teacher interview guide (Appendix M) also addresses teachers' perceptions of their students' learning, the application of the technologies, and challenges of implementation. A Teacher GIS User Questionnaire (Appendix R) was designed by examining past GIS workshop teacher interviews as well as research on the development of GIS use in the classroom (Harte, 2002; Stubbs, 2003). Using ATLAS.ti™ (Scientific Software Developments, 2003), a qualitative software package, the transcriptions of the interviews and presentations were analyzed to corroborate student understandings of the environment and GIS.

Instruments used in this study to assess spatial ability in teachers and students include the online Spatial Experience Survey (SES) for adults and students, the online Learning Styles Inventory (LSI), and the Purdue Spatial Visualization Test: Rotations (PSVT:R). The Spatial Experience Survey (SES) was modified from a questionnaire given to engineering students at Purdue University and is based on the research of Parolini (1994)

and Deno (1995). Seventy-five college students at North Carolina State University enrolled in an introductory course in GIS pretested the SES during the 2000-2001 school year. The SES collected information on factors thought to be important to the development of spatial ability such as sports, construction toys, computer games, geometry experience, age, handedness, gender, and experience in design-related courses.

The second survey was a modified learning styles inventory (LSI), based the research of Tindall (1980) and Matthews (2003) of North Carolina State University. The same seventy-five college GIS students at North Carolina State University pretested the LSI during the 2000-2001 school year. The LSI identifies the general preferences of three types of learners, auditory, visual, and kinesthetic. This inventory will be compared to the results from the SES and the PSVT: R. MOSS and CITYgreen GIS are based on visual applications in which the learner must mentally rotate three-dimensional objects like trees in order to visualize them in digital two-dimensional representations or maps. The researcher hypothesized that teachers and students who excel at visual learning would more easily attain the concepts taught by these units. Copies of the online Learning Styles Inventory and the teacher and student versions of the SES can be found in Appendices I, J, and K.

The Purdue Spatial Visualization Test: Rotations (PSVT:R) measures the ability to perform 3-D mental rotations. The instrument modified by Branoff (1999) was used in this study. Branoff (1999) found that coordinate axis labeling provided landmarks and helped the learner orient the objects in space. By modifying the test, gender differences were eliminated. Since the test was used with male and female adolescents and teachers, the

researcher felt that labeled axes would be helpful to teachers and students when orienting the drawings (Appendix H). The same college student sample was used to pretest the PSVT:R during the 2000-2001 school year. There was no time limit imposed for the thirty-question test.

The online Spatial Experience Survey (SES) for adults and students, the Learning Styles Inventory (LSI), and the Purdue Spatial Visualization Test: Rotations (PSVT:R) were administered to the study teachers and students before they began the MOSS or CITYgreen GIS units. Scores from the online survey and inventory were e-mailed to the researcher. The Purdue Spatial Visualization Test: Rotations (PSVT:R) were scored using an electronic scanning device.

DATA COLLECTION

The teacher collected and conducted all surveys, quizzes, tests, projects, and presentations during the regular class time. All groups completed the PSVT:R, SES, and Learning Styles Inventory before beginning the unit of study. These inventories took three class meetings to complete. Students who were absent completed the test or inventories upon their return to school. The objective MOSS quiz and CITYgreen quiz were administered by the teacher during the regular class time using an electronic scanning sheet after the students had collected the first set of data or about two weeks into the unit. The quizzes were scored using an electronic scanner at the school.

At the end of the unit, lab reports were completed in class that included problem question(s), hypothesis, background, materials, procedures, results, data tables and graphs,

GIS analyses steps, a final map, and conclusions. The students were guided by a student rubric (Appendix O). Students presented their findings in class in front of their peers by previously formed lab groups that had been selected by their teachers using heterogeneous grouping strategies. After the presentations, each lab group submitted one lab report and the GIS project to their teacher. Students were allowed to choose their own method of presentation. Many of the students at Leesville Middle School choose to use PowerPoint© while many of the students at Carrington Middle School choose to use the GIS program. However, some students at each school used some of each technique. Presentations were projected onto a screen in front of the class using a digital projector. A grading rubric (Appendix O) was used to score the lab reports and GIS analyses steps by the researcher, a scientist/expert GIS user, and another educator. Presentations were taped using a digital camera and a microphone and later transcribed by the researcher.

The teacher administered the objective unit test using electronic scanning sheets and the individual written conclusions using a prompt (Appendix N) at the end of the unit, after the group presentations. The objective unit tests were graded by using an electronic scanner at the school. The written individual conclusions were scored using a rubric (Appendix O) by the researcher, a scientist/expert GIS user, and another educator. All grades became a part of the student's grade for their school class.

Teacher and student interviews were conducted three weeks after the completion of the study. Twenty-four students were interviewed, 16 from the MOSS group and eight from the CITYgreen GIS comparison group or approximately two students from each class period (Table 4). Interviewees were randomly selected using a table of random numbers

from each of the possible twelve classes. Teacher input, students who did not want to be interviewed, or absent students further reduced the sample. In these cases, these students were removed from the population and the process of choosing from a table of random numbers was repeated. All students were willing to be interviewed, although five students were absent during the day of their interview. In these cases, the selected absent students were also removed from the population and the process of choosing from the table of random numbers was again repeated. A profile of the interview subjects can be found in Chapter 4. The semi-structured interviews lasted approximately 20 minutes each. The interviews were audio taped and transcribed for analysis. Table 11 contains a timetable of the data collection strategies.

Table 11: Timetable of the Data Collection Strategies

Date	Week	Experimental Group	Comparison Group
Experimental: Oct. 2002 **Comparison: March 2003**	**1**	Complete SES, PSVT:R, and LSI	Complete SES, PSVT:R, and LSI
	2 & 3	Collect 5 initial procedures, begin GIS project	Collect initial tree data, begin GIS project
	4	MOSS Quiz	CITYgreen GIS Quiz
Experimental: Nov. 2002 **Comparison: April 2003**	**5 & 6**	Formulate research group problem questions, collect materials, design data table, collect data, input into GIS project	Continue to collect tree data and begin to collect other related data such as buildings, impervious surfaces, shrubs, bare ground, etc Formulate research group problem questions
	7	Analyze data and prepare report Present findings to the class Take CITYgreen/MOSS test Write individual conclusions	Analyze using CITYgreen software and prepare report Present findings to the class Take CITYgreen/MOSS test Write individual conclusions
Experimental: Dec. 2002 **Comparison: May 2003**	**10**	Interviews of teachers and students	Interviews of teachers and students

DATA ANALYSIS

Research Question One

The MOSS experimental group and the comparison CITYgreen GIS group were compared using the quantitative measures of the quizzes, tests, analysis score, conclusion score, and lab report score. Corroboration of the quantitative analysis was investigated through qualitative analysis of data collected from student presentations and interviews. During the student interviews, students were asked to explain their answers on three environmental content and three GIS content questions from the end of the unit test. Individual written conclusions were compared to the conclusions explained by students during their interviews and presentations to gain further insight into their understandings. Student presentations, lab reports, and their GIS projects were used to determine the depth of analysis done by students.

Table 12 of the student data below summarizes the student data and the collection and analysis techniques. The quizzes and tests were scored using electronic scanning sheets with students receiving one point per item for a correct response and no points for an incorrect response. A Lab Report and Conclusion Grading Rubric were used to score the lab reports, individual written conclusions, and GIS analysis. Students could receive a maximum of five points for each of the three sections of the lab report, which were (1) results of the study, (2) data analysis, and (3) conclusion for a total of 15 possible points. Section (1), the results of the study, evaluated the information collected from the experiment including the materials used and the data collected. Section (2), data analysis, evaluated how well sense was made out of the data by using GIS to analyze patterns.

Section (3), conclusion, evaluated the appropriateness of the conclusions and possible future research questions. The individual written conclusions were scored using the conclusion section (3) of The Lab Report and Conclusion Grading Rubric with students receiving a maximum of five points for their individual written conclusions.

GIS analysis of lab groups' problem questions was scored using section (2), data analysis, of the Lab Report and Conclusion Grading Rubric. Students received five points if they did any spatial queries such as buffers and proximity relationships, four points for two or more logical queries and/or color coding, three points for one logical query and/or color coding, two points for incorrect use of color coding or logical queries, and one point for no GIS analysis (Appendix P). Student presentations, the ArcView GIS procedure log in the lab reports, and their GIS projects were also considered when using the rubric to score the GIS analyses. A maximum of five points could be received for the GIS analysis.

In order to establish interrater reliability, a random selection of two lab reports from each period, written conclusions, and GIS analyses were scored using The Lab Report and Conclusion Grading Rubric by the researcher, a scientist/GIS expert user, and another educator.

The MOSS groups at Leesville Middle School and Carrington Middle School, representing the experimental group, were expected to result in a group to be compared to the CITYgreen GIS group at Carrington Middle School with respect to the quiz scores, test scores, conclusion and analysis scores and lab report scores. ANOVAs using SAS statistical software (2003) were used to test for significant differences between the Leesville MOSS group and the Carrington MOSS group.

Table 12: Student Data

Source	Media	Interpretation Methods
Environmental and GIS understanding	MOSS quiz or CITYgreen GIS quiz	ANOVA
Environmental and GIS understanding	MOSS/CITYgreen test	Interviews and ANOVA
Lab reports	Written lab reports	Rubric and ANOVA
Individual conclusion prompt	Written individual conclusions	Rubric and ANOVA
GIS analysis of problem questions	Lab reports, student presentations, and GIS projects	Rubric and ANOVA
Lab reports presentations	Video of presentations	ATLAS.ti
Student interviews	Audiotape	ATLAS.ti
Spatial ability	PSVT:R, SES, LSI	ANOVA

Data collected from classroom observations using a field notebook by the researcher provided descriptive information relative to the instructor and student behavior and were not included in the formal statistical analysis. The interviews and presentations were analyzed for additional information that might further assess the use of GIS in schools and identify or highlight differences between the experimental and comparison group. Data from student interviews were also used to analyze perceptions regarding using GIS to perform problem-based inquiry learning in the science classroom. Of particular interest were: (a) the discernment of patterns and the identification of problem questions using MOSS and CITYgreen GIS, (b) the differences between the MOSS unit and the CITYgreen

GIS unit and regular science instruction, and (c) misconceptions regarding the environmental content or the GIS learned in the units.

Research Question Two

The PSVT:R or spatial reasoning scores were reported and analyzed as were the other variables of background experiences such as academic courses, non-academic activities, and sports, age, gender, and learning style for their possible effects on the results (Table 12). The experimental and comparison groups were expected to result in a comparable sample. Analysis of variance procedures (ANOVAs) were used to test for differences among the two groups with respect to PSVT:R, SES, LSI. The LSI was a categorical measure and each study participant was either an A for auditory learner, V for visual learner, or K for kinesthetic learner. The LSI was compared to the SES means for handedness, geometry classes, other 3D classes, shop class, sports, computer games, total SES score (the total SES score excluded age, sex, and GIS experience) and PSVT:R score to determine if visual learners scored higher on these spatial ability measures.

Each component of the SES was scored and used in the analyses for each student in the study (n=164). The components of SES were GIS experience, handedness, geometry, other 3D classes, shop class, sports, and computer games. Also analyzed were age and sex. Additionally, a total SES score including handedness, geometry, other 3D classes, shop class, sports, and computer games was compared using ANOVA procedures using SAS©. The SES mean individual and total scores were compared to the PSVT:R score.

The PSVT:R were scored using electronic scanning sheets with students receiving one point per item for a correct response and no points for an incorrect response. ANOVA

procedures using SAS© tested for significant differences between the spatial reasoning scores for students, comparing the means of age, sex, GIS experience, learning style, handedness, geometry courses, three-dimensional courses, toys, shop class, games, sports, and total SES score. The learning styles inventory and spatial reasoning score were compared to the quantitative quiz and test scores, written conclusion and analysis scores, and lab report scores using ANOVA procedures. Students' game score or computer use for playing games was verified during the student interviews as well as students prior spatial experiences such as playing sports and toys.

Research Question Three

The degree to which the teachers in the MOSS/CITYgreen GIS workshop used GIS in their classroom the school year after the workshop was investigated through the use of a questionnaire. A GIS user score was reported and analyzed and compared to the PSVT:R or spatial reasoning scores as well as the other variables of background experiences such as academic courses, non-academic activities, and sports, age, gender, and learning style for their possible effects on the results. The twelve teacher workshop participants completed the PSVT:R, LSI, and SES that were scored the same way as the student participants. Table 13 summarizes the teacher data and the collection and analysis techniques.

Table 13: Teacher Data

Source	**Media**	**Interpretation Methods**
Spatial ability	PSVT:R, SES, LSI	ANOVA
Teacher interviews	Audiotape	ATLAS.ti
GIS implementation score	Questionnaire	ANOVA Means

Teachers took a GIS User Questionnaire (Appendix R) to determine their implementation of GIS in their classrooms the second school year following the summer MOSS/CITYgreen GIS workshop. Each item on the seventeen-item questionnaire could receive a score of one as representing full implementation to a score of five as representing no implementation. Therefore, a full implementation score on the GIS User questionnaire was 17 with a higher score representing LESS GIS implementation in their teaching practice. These scores and the total scores for each question were ranked. The three teachers involved in the study were also interviewed. All qualitative data were analyzed using grounded research theory and the qualitative software program, ATLAS.ti. Of particular interest were: (a) their understandings of the environment and GIS, (b) the differences between the MOSS unit and the CITYgreen GIS unit and regular science instruction, (c) barriers to implementation of GIS in the classroom, and (d) their perceptions of student learning using the MOSS unit and the CITYgreen GIS unit.

CHAPTER 4. RESULTS

In a constructivist classroom, both quantitative and qualitative data were collected to investigate the effects of using Geographic Information Systems (GIS), a new technology, on teachers' and middle school students' understanding of environmental content and GIS. This chapter presents the results of the analyses of the data collected with the instruments described in Chapter 3. The data are presented in order by research questions. Research question one reports the results from the MOSS/CITYgreen unit test, the MOSS quizzes and the CITYgreen GIS quizzes, the related student interview questions four, seven and eight and the student interview content questions. The analyses, conclusions and lab reports are then reported with the related student interview questions two, three, five, six and nine. Research question two reports an analysis using the spatial reasoning test score as compared to the LSI and SES and the related student interview question. This is followed by a summary of the correlation analysis between the spatial reasoning test score and the unit test, quizzes, and conclusion. The third and final research question reports the results of the teachers' spatial reasoning tests, LSIs, and SESs. The GIS user questionnaires and the results of qualitative data collected from the teacher interviews are reported this final section. Descriptive statistics and tables are included in each section. A discussion of each research question and related hypotheses follows in Chapter 5.

STUDENTS' UNDERSTANDINGS OF ENVIRONMENTAL CONCEPTS

RESEARCH QUESTION ONE - UNIT TEST AND QUIZ SCORES

To address the first hypothesis that students in the MOSS group were better able to understand environmental content with GIS than were students in the CITYgreen GIS group, mean scores and ANOVAs were used to compare the quizzes and the MOSS/CITYgreen unit test. The use of classes at two different schools in two different counties taught by different teachers and the lack of a comparison group at Leesville Middle made pre-existing group differences a possibility. To further analyze these possible differences, the MOSS students (*n=131*) were compared to the comparison group (*n=33*). Then the Carrington Middle MOSS students (*n= 35*) were compared to the CITYgreen GIS students at Carrington Middle (*n=33*). The researcher tried to use a comparison group at each school but due to constraints in the school's schedule was unable to do so.

MOSS/CITYGREEN UNIT TEST SCORES

Descriptive statistics of the MOSS/CITYgreen test scores for the experimental and comparison groups by age and sex are provided in Tables 14-16. Overall, test scores were low with most students getting approximately half of the answers correct. Though students were in the seventh and eighth grades (ages 12-14), some students had been advanced a grade (ages 11-12) and others had been retained one grade (ages 14-15). Students who had been advanced a grade tended to score better (59%) than those who had been retained one grade (37%). Since all of the eighth grade students attended Carrington Middle (ages 13-15), this age discrepancy indicated that there were differences between the Carrington

Middle MOSS students and the Leesville Middle MOSS students. The ANOVA results in Table 17 indicate that there was a significant effect of age on test score ($p < .001$). Students who were older scored significantly lower on the MOSS/Citygreen test. These results may indicate that reading ability of the retained students influenced their tests scores. There were no statistically significant differences between the experimental and comparison group's tests (Table 17) when considering the Leesville MOSS and the Carrington MOSS group combined (*n=131*) as compared to the CITYgreen group at Carrington Middle (*n=33*). There was no significant difference between the sexes in the groups.

Table 14: MOSS/CITYgreen Mean Test Scores

Group	N	M	Raw Score	SD
Experimental (MOSS)	131	56%	12.3	1.6
Comparison (CITYgreen)	33	54%	11.9	2.0

Table 15: Combined MOSS/CITYgreen Mean Test Scores by Age

Age	N	M	Raw Score	SD
11	19	59%	13.0	1.3
12	83	57%	12.6	1.4
13	47	56%	12.3	1.8
14-15	15	37%	8.0	2.3

Table 16: Combined MOSS/CITYgreen Mean Test Scores by Sex

Sex	N	M	Raw Score	SD
F	67	56%	12.3	1.6
M	97	55%	12.1	1.7

Table 17: ANOVA for Experimental and Comparison Groups for MOSS/CITYgreen Test Scores by Group, Age, and Sex

$R^{2 =}$ 0.19 N = 164 F (5,158)=4.03

	df	MSE	F	p
Group	1	0.01	0.35	0.55
Age	3	0.19	7.33	0.00****
Sex	1	0.00	0.01	0.92

*p < 0.1 **p < .05. ***p < .01. ****p < .001.

The analysis was continued using just the descriptive statistics of the MOSS/CITYgreen test scores for the experimental Carrington group (*n=35*) and comparison group at Carrington Middle (*n=33*) by age and sex are provided in Tables 18-21. Table 18 indicates that while there were only 3 students ages 11-12 at Carrington, they did score higher on the unit test (M = 67%). Once again the 14-15 year old students scored lower on the unit test (M = 37%) with all of these students being at Carrington Middle. This further verifies the findings that there were significant differences between the Leesville MOSS students and the Carrington MOSS students. The ANOVA results in Table 21 indicated that there was a significant effect (p < .001) of age on test scores. Once again, students who were older scored significantly lower on the MOSS/CITYgreen test. There was a statistically significant difference between the experimental and comparison group's tests as shown in Table 21 (p < 0.1) indicating that the CITYgreen GIS group may have learned the environmental content better than the MOSS group. There were no significant differences between the sexes in the groups.

Table 18: MOSS/CITYgreen Mean Test Scores for Carrington Middle

Group	N	M	Raw Score	SD
Experimental (MOSS)	35	49%	10.8	1.8
Comparison (CITYgreen)	33	54%	11.9	2.1

Table 19: Combined MOSS/CITYgreen Mean Test Scores by Age for Carrington Middle

Age	N	M	Raw Score	SD
11	3	67%	14.7	0.7
12	20	57%	12.6	0.7
13	30	53%	11.7	1.8
14-15	15	37%	8.0	2.7

Table 20: MOSS/CITYgreen Mean Test Scores by Sex for Carrington Middle

Sex	N	M	Raw Score	SD
F	21	50%	11.0	2.0
M	47	52%	11.4	1.9

Table 21: ANOVA for Experimental and Comparison Groups for MOSS/CITYgreen Test Scores by Group, Age, and Sex for Carrington Middle

$R^{2 =}$ 0.22 N = 68 F (5,62)=3.41

	df	MSE	F	p
Group	1	0.09	2.97	0.08*
Age	3	0.16	5.28	0.00****
Sex	1	0.01	0.43	0.51

*p < 0.1 **p < .05. ***p < .01. ****p < .001.

QUIZ SCORES

Descriptive statistics of the quiz scores for the experimental and comparison groups by age and sex are provided in Tables 22-24. Each group two weeks into the six-week unit

took the 22-matching item quiz to check for initial understanding of environmental content. Overall, quiz scores were higher than test scores with most students scoring approximately 70%. Once again students ages 11-12 tended to score higher (M = 76%) than those who were in the14-15 age group (M = 49%). The ANOVA results in Table 25 indicate that there was a significant effect ($p < .01$) of age on quiz scores. This result mirrors the findings of the MOSS/CITYgreen test in which older students scored lower. There was a statistically significant effect between the experimental and comparison group's quizzes (Table 25) when considering the Leesville MOSS and the Carrington MOSS group combined (N=131) as compared to the CITYgreen group (N=33) at Carrington Middle ($p < .001$). The experimental group did significantly better on the quiz than the comparison group. There were no significant differences between the sexes in the groups.

Table 22: Mean Quiz Scores for Experimental and Comparison Groups

Group	N	M	Raw Score	SD
Experimental (MOSS)	131	71%	15.6	2.1
Comparison (CITYgreen)	33	68%	15.0	1.9

Table 23: Combined Mean Quiz Scores by Age for Experimental and Comparison Groups

Age	N	M	Raw Score	SD
11	19	76%	16.7	1.4
12	83	75%	16.5	1.8
13	47	67%	14.7	2.0
14-15	15	49%	10.8	3.0

Table 24: Combined Mean Quiz Scores by Sex for Experimental and Comparison Groups

Sex	N	M	Raw Score	SD
F	67	72%	15.8	2.0
M	97	69%	15.2	2.1

Table 25: ANOVA for Experimental and Comparison Groups for Quiz Scores by Group, Age, and Sex

$R^2 = 0.26$ N = 164 F (5,158)=9.33

	df	MSE	F	p
Group	1	0.46	13.60	0.00****
Age	3	0.14	4.08	0.01***
Sex	1	0.01	0.01	0.51

*p < 0.1 **p < .05. ***p < .01. ****p < .001.

The analysis was continued using the descriptive statistics of the quiz scores for the experimental Carrington Middle group (*n=35*) and comparison group at Carrington Middle (*n=33*) by age and sex are provided in Tables 26-28. The mean quiz score for the experimental group (53%) was lower than the mean quiz score for the comparison group (68%). The ANOVA results in Table 29 indicate that there was a significant effect of age on test scores ($p < .05$). Once again, students who were older (ages 14-15) scored significantly lower on the quiz. There was a significant difference between the experimental and comparison group's quizzes ($p < .001$). The comparison group did significantly better on the quiz as compared to the experimental group. There were no significant differences between the sexes in the groups. The quiz and the test scores for the Carrington Middle MOSS group as compared to the CITYgreen GIS group at Carrington Middle indicated that the comparison group learned the initial environmental content better than the experimental group.

Table 26: Quiz Scores for Carrington Middle

Group	N	M	Raw Score	SD
Experimental (MOSS)	35	53%	11.7	2.8
Comparison (CITYgreen)	33	68%	15.0	1.9

Table 27: Quiz Scores by Age for Carrington Middle

Age	N	M	Raw Score	SD
11	3	73%	16.0	0.7
12	20	64%	14.0	2.1
13	30	64%	14.0	2.2
14-15	15	48%	10.6	3.1

Table 28: Quiz Scores by Sex for Carrington Middle

Sex	N	M	Raw Score	SD
F	21	57%	12.6	2.4
M	47	63%	13.9	2.5

Table 29: ANOVA for Experimental and Comparison Groups for Quiz Scores by Group, Age, and Sex for Carrington Middle

$R^2 = 0.23$ N = 68 F (5,62)=3.65

	df	MSE	F	p
Group	1	0.52	10.65	0.00****
Age	3	0.16	3.18	0.03**
Sex	1	0.08	1.66	0.20

*p < 0.1 **p < .05. ***p < .01. ****p < .001

The analysis was further investigated through the addition of qualitative data collected from digital videocassettes of the students' project presentations and audiotape recordings of the student interviews at the conclusion of the MOSS or the CITYgreen GIS

units. The results obtained from the presentations and interviews provided further insight into the quantitative findings, particularly the effects of using GIS in instruction on middle school students' understanding of environmental content. Grounded theory research and a qualitative software program called ATLAS.ti© were used to analyze the qualitative data.

STUDENT INTERVIEW ANALYSIS

Student interviews were conducted to augment and clarify the previous quantitative findings and to probe more deeply into the students' understandings of environmental content using GIS. Twenty-four interview subjects, sixteen from the experimental group and eight from the comparison group or approximately two students from each class period were randomly selected using a table of random numbers from each class to be interviewed. Table 30 provides information about the students in terms of gender, school, grade, race, quiz, and unit test scores. The students are identified by pseudonyms to protect their right to confidentiality.

Table 30: Profile of Interview Subjects

Name	Gender	School	Grade	Age	Experimental (E) Comparison (C)	Race	Quiz Score	Test Score
Jilla	F	Leesville	7	12-13	E	Asian	91%	64%
Emma	F	Leesville	7	11-12	E	White	91%	68%
Andy	M	Leesville	7	12-13	E	White	86%	59%
Liz	F	Leesville	7	12-13	E	White	91%	59%
Kim	F	Leesville	7	12-13	E	White	91%	64%
Carolyn	F	Leesville	7	13-14	E	White	82%	68%
Richard	M	Leesville	7	13-14	E	White	100%	77%
Shana	F	Leesville	7	12-13	E	Black	64%	45%
Tony	M	Leesville	7	12-13	E	Black	73%	27%
Annie	F	Leesville	7	11-12	E	White	73%	41%
Susan	F	Carrington	7	11-12	E	White	77%	68%
Tim	M	Carrington	7	12-13	E	Black	86%	64%
Tyler	M	Carrington	8	13-14	E	White	86%	59%
Shanee	F	Carrington	8	13-14	E	Black	77%	59%
Blake	M	Carrington	8	12-13	E	White	82%	73%
Zach	M	Carrington	8	13-14	E	White	64%	73%
Donald	M	Carrington	7	13-14	C	White	82%	77%
Justin	M	Carrington	7	13-14	C	Black	86%	73%
Jacinta	F	Carrington	7	12-13	C	White	86%	73%
Sheryl	F	Carrington	8	14-15	C	Black	64%	64%
Carl	M	Carrington	8	14-15	C	White	86%	82%
Brittany	F	Carrington	8	13-14	C	Black	64%	50%
Andrew	M	Carrington	8	13-14	C	White	68%	55%
Erik	M	Carrington	8	13-14	C	White	86%	57%

Each interview began with the researcher reading the Interview Guide introduction (Appendix L) followed by the preliminary question, "Tell me a little bit about yourself", to engage the subject in a conversation and to help them feel more comfortable with the process. Student's responses to the preliminary question are not included in the analysis. Student responses to the remaining questions were analyzed for patterns suggestive of differences in understanding between the experimental and comparison groups.

Question Four: Tell me about what you measured and describe how you collected the data during the MOSS or CITYgreen GIS project.

All of the students interviewed in the CITYgreen GIS comparison group remembered and were able to describe what and how they collected the data. They described accurately how they measured the canopy radius, height, and diameter of the

trees using a measuring tape and a clinometer. They also described how they located and measured the other features on their school campus such as air conditioners, shrubs, impervious surfaces, and buildings. Brittany said, "We measured the trees. We took the height using the clinometers. We also measured the diameter breast height and observed how healthy the tree were and what kind of obstructions were in the way of it. We also measured the canopy radius using tape measurers from the outer tree limb. We measured buildings and decided what was bare, grass, shrub, impervious surface, building or forest patch".

Students' interviewed in the MOSS group could easily name the five initial procedures of abiotic, vegetation cover, pitfall traps, trees, and animals for which they collected data initially. However, in MOSS, students divided into five groups, each group performing one of the five procedures. Students could only accurately describe how they collected the data for their group of abiotic or vegetation cover or pitfall traps or trees or animals, even though they shared with each other what each group had done and every student had read and discussed all five procedures.

This finding emphasizes the importance of direct student experience on learning and recall of information. Student's remembered what they had done. The CITYgreen GIS group was able to more accurately describe what they had done during the experiment.

Question Seven: Do you think that learning GIS is important?

All students felt that learning GIS was important. The CITYgreen GIS students emphasized that GIS tells you about the environment and what might happen in the future. They felt that it "compared the data" and "helped you to make better decisions". The MOSS students gave a variety of reasons why they felt learning GIS was important. They

said that it "helps you to organize lots of data and to fit everything together". They gave examples such as, "you could see the differences in soil temperature and know where to grow plants" or "you can find out where animals live". But they also gave other examples that were not related to the MOSS project such as, "you could track criminals, 911 uses it, firefighters could use it, the military uses it to keep track of the troops, and it is used to determine bus routes". Finally two MOSS students felt that GIS was important because it helped them to solve problems and "it taught you to be accurate".

Students in general said that GIS helped you to organize lots of data and to understand and compare all of the information in order to solve problems. The CITYgreen GIS students who used modeling understood how GIS could be used to make better decisions and plan for the future. The MOSS students focused on relationships in their 10m by 10m plot but also gave other examples of everyday uses of GIS. They understood better how use GIS to solve problems and show relationships.

Question Eight: What other ways do you think GIS could be used in your studies?

Fifteen out of 24 students (63%) felt that if they used GIS in another subject it would be mathematics. Reasons given for this answer were "because you plot things", "the graphing and numbers", "perimeter, area, and distances", and "multiplication and operations". This agrees with students' comments in question three (following section) in which they said that using GIS was different than their normal science class because it involved more mathematics.

Eight out of 24 students (34%) said that social studies would be the other subject in which they would use GIS. Reasons given were "…to study different countries and landforms", "population density", "maps and to compare other countries", and "to study

changes in the past like battlefields, how they looked in the past compared to now". Since maps skills are studied in social studies in middle schools this is a natural connection for students.

One student out of 24 students (3%) said that language arts was important because, "You need good reading skills because there are a lot of directions and you need to understand what you are doing". Though GIS is a visual language, the reading and understanding of directions is very important to successful use of GIS.

The results from the quantitative data on the unit test and quizzes and the qualitative data indicates that students in the CITYgreen GIS group were able to learn the environmental content better than the MOSS group and that there were differences in student learning between the two GIS curricula.

STUDENT INTERVIEW CONTENT ANALYSIS

At the end of the student interviews, students were asked three environmental and three GIS questions from the unit test to further identify or highlight differences in understanding of content between the experimental and comparison groups.
In addition, understandings regarding the differences between the MOSS curriculum and the CITYgreen GIS curriculum were further investigated. Students were asked to respond to the following open-ended items from the unit test:

Environmental Content

1. What does it mean to study the abiotic and biotic components of the environment?

2. What is the name of the books you used to look up the names of things?
3. What does DBH mean?

GIS Content

4. What is GIS?
5. How does it work?
6. What does it do?

To analyze the questions the student responses were sorted into one of the following categories and analyzed using ATLAS.ti©:

1. Correct
2. Correct/Incorrect (one part right/ the other part wrong)
3. Incorrect

The distributions of the content questions by type of response are shown in Table 31. A comparison of student responses revealed that the comparison group learned the environmental content better than the experimental group. However, overall the experimental group (M=75% for correct responses) learned the GIS content better than the comparison group (M=53% for correct responses).

Table 31: Student Interview Reponses to Environmental and GIS Content

	Experimental (MOSS)						Comparison (CITYgreen)					
	Question Number						Question Number					
	Environmental			GIS			Environmental			GIS		
RESPONSE TYPES	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
Correct	88	100	38	69	62	94	100	100	100	87	0	71
Correct/Incorrect	12	0	50	25	31	0	0	0	0	13	88	29
Incorrect	0	0	12	6	7	6	0	0	0	0	12	0

Note. Response types are in percentages.

Environmental Content

All the students in both groups could easily responded to question number two, answering "field guide" 100% of the time. The overall problem question for both groups was how do the abiotic and biotic components of the environment relate to each other (question number one). The comparison group answered correctly more often than the experimental group (100% compared to 88% respectively), however the experimental group mentioned relationships 86% of the time as compared to the comparison group, which mentioned it only 36% of the time as determined through coding using ATLAS.ti. Since students in the MOSS group had to create their own relationships from the data they collected, they seemed to be more aware of them. Students in the comparison group were much better at explaining the meaning of the tree measurement "diameter breast height", (question three). CITYgreen GIS is based on tree measurements and all students in the

comparison group repeatedly measured the diameter breast height of the trees. Only the MOSS students who were in the tree group or had chosen an individual problem question related to trees measured them. These students responded correctly, explaining the measurement completely. These findings show that students who had direct experiences, such as measuring trees or creating relationships among the data, understood the information better than students who had indirect experiences with the information, for example classroom explanations or readings.

GIS Content

Even though overall the experimental group learned the GIS content better than the comparison group, the comparison group was better able to explain question number one, what is GIS, than the experimental group (87% correct to 69% correct responses respectively). In general students' responses discussed visualizing data in layers and performing analyses. The comparison group had a better overall view of GIS. For example, Justin from the comparison group said, "A program that helps you to analyze the environment" whereas Andrew from the experimental group said, "It is a visual way of seeing where you are and where you need to go. It makes maps using layers". The experimental group focused more on using coordinates to "sort things out in an area" while the comparison group focused on environmental analysis and modeling. In CITYgreen GIS, students performed an ecological analysis of their school grounds using an aerial photograph. The models produced by the program allowed students to make future predictions, helping them to better understand the power of GIS in making important environmental decisions. Students in the comparison group focused more on experimental

design and data analysis in a 10m by 10m plot, searching for patterns using GIS to solve their problem questions.

Students in the experimental group answered questions number two and three, how does it work and what does it do, correctly more often than the experimental group (Table 31). No students in the comparison group correctly answered the question, how does GIS work. Their answers pertained to putting data into the computer and getting an answer. For example, Jessica said, "GIS works by entering the information and it calculates all the stuff for you. It is not like a spreadsheet, it is more like a visual format". The comparison group collected data, drew polygons on the aerial photograph using a process called digitizing, entered the data, and the program used predetermined models to analyze the information. Making changes to the map and rerunning the models multiple times easily accomplished future predictions. In contrast the experimental group focused on asking questions and using layers of information to solve problems. They described how GIS worked by explaining, "you turn layers on and off, you use points, lines and polygons, by processing information into a table, changing the table into a shapefile, and then piling the layers together into one project". Since the experimental group conducted their own analyses of the data using GIS, they had a better idea of how the program worked.

When students were asked what does GIS do (question six), both groups identified that GIS solved problems, answered questions, and showed relationships. The experimental group discussed change, patterns, and relationships as well as creating questions whereas the comparison group explained that GIS made maps from data and predicted the future. Shana from the experimental group said, "It creates relationships among geographic things,

objects and measurements. All the answers are different. It creates more questions from the problems". In contrast Donald from the comparison group said, "It analyzes everything you put in after you complete it and it tells you what you might want to change and how it would become better or worse".

These findings suggested that the CITYgreen GIS comparison group was able to learn the environmental content better than the MOSS group. Since there were likely differences between the two schools, the comparison for the Carrington Middle groups (MOSS and CITYgreen GIS) were probably more equivalent. These findings also indicate that there are differences between the MOSS curriculum and the CITYgreen GIS curriculum. Students in the MOSS groups understood better how to use GIS to solve problems and show relationships.

RESEARCH QUESTION ONE - ANALYSIS, CONCLUSION, AND LAB REPORT SCORES

Performance assessment is an approach to evaluating students by directly examining their performance on tasks. The tasks have a direct relationship to the real-life event. In order to evaluate the tasks, grading rubrics, based on scoring values and objectives are often used (Gall, Borg, & Gall, 1996). The performance assessments of analysis, conclusions, and lab reports were evaluated using a grading rubric. Group scores were given for the analysis and the lab reports. Individual conclusions were written in paragraph form by each student as part of the unit test and scored individually. The researcher, a scientist/expert GIS user, and another educator scored the written conclusions, analysis, and lab reports, providing an interrater reliability of 80%.

Descriptive statistics of the analysis, conclusions, and lab report scores for the experimental and comparison groups by age and sex are provided in Tables 32-35. The mean lab report score for the comparison group was 82% as compared to the mean score of 74% for the experimental group (Table 32). However, Table 35 shows that they were not significantly different. Age of student again made a difference in the lab report score, but this time the older students (ages 14-15) scored significantly higher on the lab reports ($p < .01$). There were no significant differences between the sexes in the groups.

A maximum of five points could be received for the GIS analysis. Students received five points if they used GIS to perform an in-depth analysis of the problem question. Overall, analysis scores were higher and statistically significant ($p < .05$) for the experimental group ($M = 78\%$) as compared to the comparison group ($M = 74\%$). Age of the student did make a difference in the analysis score with the older students (ages 14-15) scoring significantly higher ($p < .01$). There were no significant differences between the sexes in the groups. Students who were older (age 14-15) scored higher on the lab reports and the GIS analysis, which were both group scores.

The results of the individual written conclusions reflect the earlier findings of the MOSS/CITYgreen test in which older students (age 14-15) scored lower ($p < .05$). There were significant differences between the experimental and comparison group's conclusions (Table 35) when considering the Leesville Middle MOSS and the Carrington Middle MOSS group combined as compared to the CITYgreen GIS group at Carrington Middle ($p < .01$). The comparison group was significantly better on the written conclusions than the experimental group. There were no significant differences between the sexes in the groups.

Table 32: Analysis, Conclusion, and Lab Report Scores for Experimental and Comparison Groups

		Means		
Group	N	Analysis	Conclusion	Lab Report
Experimental (MOSS)	131	78%	63%	74%
Comparison (CITYgreen)	33	74%	70%	82%

Table 33: Combined Analysis, Conclusion, Lab Report Scores by Age for Experimental and Comparison Groups

		Means		
Age	N	Analysis	Conclusion	Lab Report
11	19	62%	69%	69%
12	83	74%	64%	76%
13	47	77%	66%	73%
14-15	15	81%	53%	84%

Table 34: Combined Analysis, Conclusion, Lab Report Scores by Sex for Experimental and Comparison Groups

		Means		
Sex	N	Analysis	Conclusion	Lab Report
F	67	72%	67%	74%
M	97	75%	63%	75%

Table 35: ANOVA for Experimental and Comparison Groups for Analysis, Conclusion, Lab Report Scores by Group, Age, and Sex

Source	df	Analysis		Conclusion		Lab Report	
		F	p	F	p	F	p
Group	1	6.41	0.01**	9.75	0.002***	1.75	0.19
Age	3	4.74	0.003***	3.50	0.02**	4.07	0.008***
Sex	1	0.04	0.85	1.61	0.20	0.07	0.79

*p < 0.1 **p < .05. ***p < .01. ****p < .001.

Descriptive statistics of the analysis, lab report, and conclusion scores for the experimental Carrington Middle group and comparison group at Carrington Middle by age and sex are provided in Tables 36-39. The mean lab report score for the experimental group was 79% compared to the mean score for the comparison group of 83%. However, the ANOVA results in Table 39 indicate that there was no significant effect between the lab report scores in the two groups. There were no significant effects of age and sex on lab report scores.

There were significant differences between the experimental and comparison groups GIS analyses ($p < .01$) as shown in Table 39. The MOSS group did significantly better on the analysis than the CITYgreen GIS experimental group. There was a significant difference in the GIS analyses score between the experimental Carrington Middle group and comparison Carrington Middle group when comparing the means of age and sex ($p < 0.1$). Older students (ages 14-15) did significantly better on the GIS analysis as compared to the younger students (age 11), as did males as compared to female students.

The results of the individual written conclusions were similar to the experimental and comparison groups as shown in Tables 32 - 35. There was a statistically significant

effect between the experimental Carrington Middle group and comparison Carrington Middle group when comparing the means of the conclusions as shown in Table 39 ($p < .01$). The comparison group scores were significantly better on the written conclusions than the experimental group. There were no significant effects of age or sex on the conclusion scores.

Table 36: Analysis, Conclusion, and Lab Report Scores for Carrington Middle

		Means		
Group	N	Analysis	Conclusion	Lab Report
Experimental (MOSS)	35	79%	58%	79%
Comparison (CITYgreen)	33	74%	70%	82%

Table 37: Analysis, Conclusion, Lab Report Scores by Age for Carrington Middle

		Means		
Age	N	Analysis	Conclusion	Lab Report
11	3	68%	66%	80%
12	20	73%	66%	81%
13	30	79%	67%	79%
14-15	15	81%	55%	85%

Table 38: Analysis, Conclusion, Lab Report Scores by Sex for Carrington Middle

		Means		
Sex	N	Analysis	Conclusion	Lab Report
F	21	72%	67%	74%
M	47	78%	63%	75%

Table 39: ANOVA for Experimental and Comparison Groups for Analysis, Conclusion, and Lab Report Scores by Group, Age, and Sex for Carrington Middle

Source	df	Analysis		Conclusion		Lab Report	
		F	p	F	p	F	p
Group	1	10.55	0.001***	9.07	0.003***	2.54	0.10
Age	3	2.49	0.069*	1.91	0.14	2.08	0.11
Sex	1	3.43	0.08*	0.10	0.75	2.33	0.10

*p < 0.1 **p < .05. ***p < .01. ****p < .001.

Table 40 summarizes the results of testing the hypothesis that the students in the MOSS group were better able to learn the environmental content with GIS than the students in the CITYgreen GIS group.

Table 40: Summary of Results for Unit Test, Quiz, Analysis, Conclusion, Lab Report by Group

Group	Unit Test	Quiz	Analysis	Conclusion	Lab Report
Experimental	x	+	+		x
Comparison	x			+	x
Experimental (Carrington)			+		x
Comparison (Carrington)	+	+		+	x

Note. + is significantly, x = no change

The CITYgreen GIS comparison group scored significantly better on the written conclusions but the MOSS experimental group scored significantly better on the GIS analysis. Students ages 14-15 scored significantly lower on the individual assessments that required reading and writing abilities such as the unit test, quiz, and written conclusion but they scored higher on the group score of lab reports and the GIS analysis. Additional comparisons between the MOSS and CITYgreen GIS groups in relation to their conclusions, GIS analysis and lab reports were explored using qualitative data from the student presentations and interviews.

Question Two: Tell me what you thought about the MOSS or CITYgreen GIS units. What did you like, what did you not like?

Students overall liked the MOSS and CITYgreen GIS units. They said that it was interesting and very different from what they would normally do in science class. For example, Tony said, "It is cool and you are going to get to use the computer". Students in both the experimental and comparison groups gave similar responses to what they liked and did not like about the units. Students said that they enjoyed going outside (50%), being on the computer and plotting things (30%), collecting the data (15%), and formulating an individual problem question (5%). Jacinta said, "The GIS part of it was cool and I liked making maps on the computer".

Students said that they did not like that it took six weeks to complete the unit because "it was too long", nor did they enjoy that they needed to be accurate and write things down. Some students reported that their groups did not work well together which made things more difficult for everyone. Two students reported that they did not enjoy entering the data into the computer because "it was tedious" and one student said that they did not like getting dirty. Two students said that they did not like the presentations because "it made them nervous" and one student reported that he did not like taking the unit test.

Overall students seemed to enjoy the MOSS and CITYgreen GIS units because they got to go outside, collect data, and use the computers. Students did not enjoy the more tedious and repetitive tasks of data entry, which required accuracy and two students did not like the assessments of the units (presentations and unit test).

Question Three: How does the MOSS or CITYgreen GIS project compare to what you normally do in your science class?

Jacinta said, "It was a big leap. We started off with little labs and the next thing you know we were outside every day working on the ground. Most of our labs were very small. This was a big jump to go from a one-day thing to a one-month thing. I had never done it before but I liked it". Students from Leesville Middle all had the same science class but the students from Carrington Middle, since they were in an elective class, came from different science classes throughout the school. Regardless of the students' science class, the answers from students were the similar. Students said that in science class they read the book, took notes, watched films, answered questions, and did worksheets. When they did labs, they were one period in length. They never went outside nor used the computer in science class.

Students said that the MOSS and CITYgreen GIS units were different from what they normally did in science class because they:

- went outside
- used the computer
- did more mathematics
- worked longer and more in-depth.

Zach summarized the difference by stating, "everybody was doing a different project and there was no book to follow" and Emma said, "It was not just reading out of the book, you actually got to go outside and do it".

Question Five and Six: Please explain a pattern that you noticed from the project.

Students were able to explain many patterns that they noticed from the projects. In the CITYgreen GIS group students noticed that they had a lot of Bradford Pears near their school and that they were all approximately the same height. Brittany said, "They do not provide good wildlife benefit. They basically were planted for decoration because they have flowers on them". Students were surprised by how many trees and how many different kinds of trees there were on their campus. During the project, a million dollar school renovation and expansion project was in progress. Students began to think about what the effects would be of the new construction. They realized from the CITYgreen GIS program that fewer trees would mean decreased pollution benefits and fewer places for animals to live. They also realized the importance of larger trees and replacing trees that had been eliminated as the result of the construction. Carl said, "The more trees and the less buildings the more benefits you have. The more trees the less runoff there was".

The MOSS students were also surprised by the patterns they found in their study sites. Many students noticed that there were more insects in the sunnier areas or in the grass. Students were surprised because they thought that more animals would be in the woods where they could hide and be in the shade or in the trees and shrubs where they could eat leaves.

One student was surprised that the soil temperature was colder than the air temperature. Students thought that the soil would be warmer than the air. Students also thought that the soil under the pine needles would be cooler since it was in the shade. They were surprised to find that the soil temperature under the pine needles was warmer than the cooler fall air temperatures.

Students were surprised by how many living things they found in a 10m x 10 m plot. One group counted over 500 ants and another thought there would be 3,000 blades of grass and instead found over 3,000,000 blades of grass. The Carrington Middle study site contained a pond and students thought that more animals would be closer to the pond because "animals like water". They were surprised to find the opposite instead, "more animals were found further away from the pond where there was more sun". Shanee wondered what happened to the animals in the pond when the weather got cold. So she "tried an experiment and put a bug in a bowl and then in the freezer. When I pulled it out the animal was still living and it was the same size. I was surprised it was still alive". Jilla said, "Everything is linked together like the air and the temperature with the soil and the animals in the ground and what is on top of the ground".

Both groups were surprised by what they found outside their school campus. Students had previous ideas that were tested and often disproved by their results. They began to understand the connections between the different components in the environment.

Question Nine: Do you think your ability to solve scientific problems has changed as a result of this project and if so how?

All students interviewed said that their ability to ask scientific questions had improved. They said, "it is easier to do now and I can think of them (problem questions) more easily". Donald further explained that he now understands the steps to solving problems when he said, "I can now think about how to solve problem questions. I know how to do it and the steps of how to do it". Students commented that they solved problems over and over again during the GIS units. Erik said, "I can now ask questions that make sense and have more depth". Carl said, "I look at different ways to answer questions now".

Three students expressed a deeper understanding of asking questions when they said, "I learned you should ask a lot more questions when you do something that is complicated". Two students seemed to understand science better when they said, "I never knew there was that much stuff to science and I didn't realize how important it was when I started the project".

While student comments did not clearly identify whether or not their ability to solve scientific problems had changed, they did show that students now had an idea of how to go about solving problems and that their ability to identify or formulate problem questions had improved. During the interviews in question five and six, students were easily able to explain and discuss a variety of problem questions. When they began the unit and tried to write problem questions at the bottom of their quizzes, all of the classes needed further explanation on how to identify and write problem questions. There was a dramatic difference between problem identification and the understanding of the steps of skillful problem solving from the beginning of the GIS units to the end of the GIS units as explained by the students in these interviews.

Students commented that the units were longer and more involved than what they usually did in science. Two students, one from the MOSS group and one from the CITYgreen GIS group said that they now understood why science was important. Students began to see that science was not just a collection of facts but rather an in-depth investigation of problem questions to which there were no definitive answers.

STUDENT PRESENTATION ANALYSIS

Student presentations provided additional information that might further explain the differences between the MOSS experimental group and the CITYgreen GIS comparison groups. Student presentations were transcribed and, using inductive reasoning, categories were allowed to emerge to create a rich description of each group.

MOSS Group

The MOSS group had more questions when they finished the project than when they began. Seventy percent of the students said they failed to prove their original hypothesis compared to 56% of the CITYgreen GIS students. Six of the thirty-two lab groups indicated that they would have done their procedure differently. Leslie said, "We wish we would have had more time to dig a hole in each vegetation cover so we could have seen a difference in leaf litter and other vegetation". Four of the lab groups wished they could change their problem question. Many of the students recognized that their problem questions were too narrow and only contained one variable instead of two. Megan said, "I learned that it is really, really hard to make your own problem question and to try and make your own procedure to answer it" and Chris said, "If I had to do this lab again, I would have two variables instead of one".

MOSS students, puzzled by their unanswered questions, engaged in deep reflection. Students questioned the way they performed the experiment. Ten of the 32 groups said that they should have collected more data. Five groups wished they had collected more accurate data, two groups wanted to change the study site, and three groups would like to use different equipment. Angela said, "If I repeated this experiment I would want a bigger

study site with more different types of vegetation". Dave said, "If we did this again we would use a different auger rather than a mini auger and dig down deeper. There may be different types of soils deeper down." Five groups explained how they would investigate multiple alternatives. Elizabeth reported that next time they would "…measure how deep the leaf litter is…measure the air temperature to decide if it has an effect on soil temperature or if the leaf litter blocks the air".

When asked what they would do differently next time, some MOSS students analyzed how they could have worked together better. Five groups identified that working together "saved a lot of time", two groups wished they would have divided the tasks more evenly, one group explained that they needed to save more frequently on the computer, and one group said they could put their project online to share with others. Many students during the interviews expressed that working collaboratively was very important to the success of their projects.

These results indicate that MOSS students were engaged in problem solving and inquiry. Oftentimes in a problem-solving investigation, students end up with more questions than when they began. The questions led to deep reflection and discussion on what they would do differently next time.

CITYgreen GIS group

There were surprises in the CITYgreen GIS group too. Students were surprised when they found out what a big difference trees made to the environment. Martin said, "Our biggest surprise was that a few amount of extra trees would save Carrington over $500.00/year". Other groups realized that when they increased standing water, trees would

decrease and animal habitat would be lost. Terrell said, "We went from 23 species to 14. We were surprised how many animal habitats were lost". And many groups realized that adding impervious surfaces would result in fewer trees and shrubs and less storm water benefit. Sierra said, "With the school remodeling, if we could make a suggestion it would be to tell them not to build a whole lot of impervious surfaces". One group that analyzed only the trees around the buildings concluded, "We would add more trees around campus. We would not plant trees like Bradford pears but would plant other trees that are better for wildlife like red oaks".

However, students felt like they had the answers when they were finished with their projects, even though 56% of the groups said they had “disproved” their original hypothesis. There were fewer reflections regarding how they would do things differently next time. They felt that they had "gotten it right" and that the GIS program had given them the answers. Students said, "Using CITYgreen solves many types of problems related to the environment. With this type of problem solving you can see what would happen in the environment before you do it", and "CITYgreen can tell you anything about the environment". The CITYgreen GIS software program is designed to give you answers by performing predetermined models based on the information provided. Students were impressed by the modeling capabilities of the program and focused on future predictions for their school. Richard said, "We can learn to find a solution to the given data and it gives us more knowledge about the environment and what we need to do in order to protect it".

Students said that the MOSS and CITYgreen GIS units were different from what they normally did in science because they went outside, used the computer, did more

mathematics, and worked longer and more in-depth. Students learned how to ask problem questions and they had an idea of how to go about solving problems. Their problem identification skills improved dramatically. There were many surprises for students as they found their hypotheses were not supported. The MOSS students had more questions and engaged in deeper reflection than the CITYgreen GIS students who felt they "had the right answer". However, the CITYgreen GIS students were able to use modeling and identified that GIS could be used to solve environmental problems in the future. These qualitative results support the quantitative results that there were differences in the environmental content learned with GIS during the MOSS and CITYgreen GIS curricula.

SPATIAL REASONING TEST SCORE COMPARED TO LSI AND SES

Research Question Two

To address the hypothesis that students who are visual learners and have more significant predictors on the SES will be more successful on the PSVT:R test, an ANOVA was used to compare the spatial reasoning test score (PSVT:R) to school or group, sex, GIS experience, learning style as reported on the LSI, and factors on the SES such as handedness, academic courses (geometry, shop class, 3-D courses), non-academic activities (toys, computer games), and sports activities. Based on these results, Table 41 reports the means of some of the possible success predictors. Sex ($p < .001$), shop class ($p < .05$), and computer games ($p < .05$) were significantly different when compared to spatial reasoning scores (Table 42). Males scored higher than females on the spatial reasoning test, students that played computer games scored higher than those who never played computer games, and the fewer shop classes taken the higher they scored. Most students (60%) seemed to

play computer games weekly or daily. Learning style, school, handedness, sports, age, or geometry and 3-D classes did not significantly affect the spatial reasoning test scores.

Table 41: Mean Scores for Spatial Reasoning Test by Sex, Learning Style, Handedness, Games, and Shop Class

Source	N	M	Raw Score	SD
Spatial Test Score				
Carrington MS	68	52%	15.6	1.9
Leesville MS	96	56%	16.8	1.4
Sex				
F	67	37%	11.1	1.6
M	97	44%	13.2	2.1
Learning Style				
Auditory	51	41%	12.3	2.2
Kinesthetic	57	42%	12.6	2.0
Visual	56	41%	12.3	1.9
Handedness				
Right	128	40%	12.0	2.0
Ambidextrous	18	49%	14.7	1.7
Left	18	37%	11.1	1.9
Games-computer				
Never	10	40%	14.4	2.3
Few months	30	50%	10.2	1.9
Monthly	25	48%	11.4	1.5
Weekly	41	53%	14.1	2.1
Daily	58	48%	12.0	2.0
Shop Class				
None	95	46%	13.8	1.6
One year	61	38%	11.4	1.8
Two years	8	25%	9.25	2.0

Table 42: ANOVA for Spatial Reasoning Test Score by LSI and SES

$R^2 = 0.31$ N = 164 F (36,127)=1.56

Source	df	MSE	F	p
Group	1	0.003	0.11	0.74
Age	3	0.001	0.06	0.98
Sex	1	0.49	14.68	0.000****
Learning Style	2	0.010	0.31	0.73
GIS Exper.	1	0.004	0.11	0.73
Geometry	2	0.02	0.59	0.55
3-D courses	3	0.002	0.08	0.97
Handedness	2	0.07	2.10	0.127
Toys	5	0.06	1.76	0.126
Shop Class	2	0.12	3.54	0.03**
Games	4	0.098	2.97	0.02**
Sports	10	0.50	1.52	0.14

*p < 0.1 **p < .05. ***p < .01. ****p < .001.

Additional data regarding student computer use was collected during the interviews.

Question One: Tell me about your science background and your experience with computers.

All students interviewed reported that they liked science. They remembered a wide variety of science subjects and topics that they had studied in the past from physics and topics such as sound, light, levers, pulleys, and laws to earth science and topics such as erosion, volcanoes, and plate tectonics to other science subjects such as chemistry, astronomy, evolution, biology, and environmental science. Twenty-three of the twenty-four students interviewed reported that they liked computers and used them regularly. This agrees with the results of the SES in which most students (60%) seemed to play computer games weekly or daily.

Students reported a wide variety of computer uses with 63% playing computer games, 54% using the Internet and emailing their friends, 38% doing their homework, and 33% doing research projects. Individual interests mirrored a variety of computer uses. For

example, one student said that he liked painting on the computer because he was interested in art, another student played math games because math was his favorite subject, two students did research about animals, one specifically about horses because she was a horseback rider and others listened to and downloaded music. One girl visited dance websites because she was a dancer.

This finding indicates that students in general have positive attitudes toward computers and science and that they use computers for a variety of tasks related to school and personal interests. Which computer tasks, if any, that could improve students' spatial reasoning ability, will need to be further investigated.

SPATIAL REASONING TEST BY UNIT TEST, QUIZZES, AND CONCLUSIONS

Consideration was given to the possibility that if an individual preferred learning visually or had a higher spatial reasoning ability then he or she would possibly score better on the unit test, quizzes and/or the written conclusions. Lab reports and analyses were not considered because these were group scores. The learning style or a visual preference for learning did not significantly affect the spatial reasoning test score (Table 43). An ANCOVA tested the hypothesis that the unit test scores, quiz scores, or the written conclusion scores were related to the spatial reasoning tests. Results indicated that there were no significant differences between the MOSS and CITYgreen GIS students or the conclusion scores. There was a significant difference ($p < .05$) between the spatial reasoning test scores on the unit tests and quizzes ($p < 0.1$) as shown in Table 43. Students who scored higher on the spatial reasoning test also scored higher on the unit test and the

quiz. Such findings support the hypothesis that students who have better spatial reasoning ability may better be able to learn environmental science content.

Table 43: ANOVA for Spatial Reasoning Test Score by Unit Test, Quizzes and Conclusions

$R^2 = 0.25$ N = 164 F (4,159)=5.70

Source	df	MSE	F	p
Group	1	0.01	0.47	0.49
Unit Test	1	0.15	4.61	0.03**
Quizzes	1	0.12	3.60	0.06*
Conclusions	1	0.07	2.15	0.14

*p < 0.1 **p < .05. ***p < .01. ****p < .001.

GIS USER QUESTIONNAIRE, SPATIAL REASONING TEST, LSI, AND SES

Research Question Three

The twelve teachers in the MOSS/CITYgreen GIS workshop also completed the spatial reasoning test, LSI, and SES. Additional background information was reported such as years of teaching, grade level and subject taught, and areas of licensure. Teachers attended the workshop in the summer and were supported as they implemented the GIS curriculum the following school year.

At the end of the next school year or two years after the summer workshop, teachers were asked to complete a 17-item questionnaire regarding the degree of GIS implementation in their classroom teaching (Table 41). A score of one or two indicated use of GIS to a great extent, a score of three indicated use of GIS often, and a score of four or five indicated little or no use of GIS. Every teacher in the workshop responded to the questionnaire. Overall a mean score of 3.5 or a rating of often was reported regarding GIS implementation. Seventy-five percent of the teachers in the workshop reported using GIS in their teaching with twenty-five percent reporting using it little or not at all.

Table 44 shows that most teachers were able to install the software on the computers at their schools (M = 1.6), had confidence teaching using GIS (M = 1.9), had presented GIS at conferences (M = 2.4), and had even taught a course using GIS in their schools (M = 2.7). When the three teachers in the study from the workshop were interviewed and asked how confident they were in using GIS in their classroom, they all responded to a great extent. This significantly contrasts to the mean confidence rating of four or little or none that teachers reported at the end of the MOSS/CITYgreen GIS summer workshop. All of the teachers reported using the MOSS curriculum the following school year after the summer workshop and most (M=2.4) the next school year. In contrast, little or none (M=4.1) used the CITYgreen GIS curriculum in their schools even though they were supplied with the software, equipment, and data needed for the project.

Many of the teachers had presented their GIS projects to the faculty (M=3.0), taught another GIS unit (M=3.0), taught another teacher GIS (M=3.0), created their own GIS project (M=3.2), attended other GIS workshops (M=3.2), taught a GIS workshop (M=3.2) or had written grants to fund their GIS projects (M=3.6). These results show an integration of the use of GIS into these teachers' curricula. The three teachers involved in the study all reported being recognized by their administration for their projects and had shared their GIS projects with faculty and other teachers.

The items identified as little or none (M=4.0 - 4.3) were creating a GIS curriculum or course, using CITYgreen in the classroom, using GIS as part of an award, and attending a GIS college course. Teachers attended GIS college courses less frequently, emphasizing the importance of offering GIS workshops for teachers. Though they were comfortable

with using GIS in their classrooms and creating their own lessons, units, and projects, they were less comfortable with creating their own curriculum or courses. This emphasizes the importance of providing GIS curriculum for classroom use.

Table 44: Means for GIS User Questionnaire and Ratings

GIS User Item	Mean Score	Rating
GIS on computers	1.6	Great Extent
Confidence	1.9	Great Extent
MOSS in class	2.4	Great Extent
Present at conferences	2.6	Great Extent
Teach a course using GIS	2.7	Great Extent
Present to faculty	3.0	Often
Teach another GIS unit	3.0	Often
Teach another teacher GIS	3.0	Often
Create own GIS project	3.2	Often
Attend other GIS workshops	3.2	Often
Teach a GIS workshop	3.2	Often
Grants to do GIS	3.6	Often
Create a course using GIS	4.0	Little or none
Create GIS curriculum	4.0	Little or none
Use GIS as part of an award	4.0	Little or none
CITYgreen in class	4.1	Little or none
Attend GIS college class	4.3	Little or none

An ANOVA was used to compare the spatial reasoning scores with learning style as reported on the LSI, years of teaching experience, and factors on the SES such as handedness, academic courses (geometry, shop class, 3-D courses), non-academic activities (toys, computer games), and sports activities. There were no significant effects of learning style, handedness, academic courses, non-academic activities, nor sports on spatial reasoning test scores. There was a significant difference effect of the years of teaching experience ($F = 11.03$, $p < .05$) on the spatial reasoning test score. It was found that the greater the number of years of teaching experience, the lower the spatial reasoning test scores.

An ANOVA was used to compare the effect on the number of years of teaching experience to the GIS User Questionnaire ratings. There were no significant effects of the GIS User Questionnaire rating on the number of years of teaching experience. These findings suggest that most teachers, regardless of experience, can implement GIS into classroom instruction.

It is interesting to note that all the teachers in the workshop, except for one teacher who was an auditory learner, reported being a visual learner on the LSI. These results could indicate that teachers who are visual learners are more likely to implement GIS into their instruction or that they were expecting a visual presentation of information which made them more likely to choose the visual responses on the LSI.

Supporting the hypothesis that at least half the teachers would continue to demonstrate use of GIS in their classrooms for instruction the school year after the MOSS workshop, all of the teachers in the workshop used GIS the school year following the summer workshop and 75% of the teachers are still often using GIS in their classroom instruction two years after the summer workshop.

TEACHER INTERVIEW ANALYSIS

Question One: How confident are you in teaching and using GIS in your classroom?

Out of a scale of 1 to 5 with 5 being confident, all three teachers rated themselves a 4 or "moderately confident" with teaching and using GIS in their classrooms. This agrees with the overall results found in the GIS User Questionnaire (Table 41). Teachers said that there was always room for improvement and realized that GIS was not a static study and said that "there is a lot more out there".

N.D. who used the CITYgreen program said that while he was comfortable with entering data and digitizing, he was not comfortable with the modeling, which was very important to him because, "that is what separates the CITYgreen GIS project from the MOSS project…my goal is to be able to use it for the modeling". This also agrees with results from the GIS User Questionnaire (Table 44) in which most teachers reported using CITYgreen little or not at all the following year.

Question Two and Three: What do you feel your students have learned or how have they benefited from the MOSS or CITYgreen GIS unit?

Out of a scale of 1 to 5 with 5 being high, all three teachers said they felt their students learned and benefited a 4 or as one teacher stated, "I think that a lot of the things they were learning, they were not even aware that they were learning them". The teachers said that they felt the students became more observant and were able to identify relationships and patterns. Carolyn felt that her students also learned to ask problem questions. N.D. said that they learned to collect their data from the field and to manipulate it using the computer. Pat explained that she thought that the difference between taking the data outside to creating representations on the computer was an important spatial reasoning skill. She also felt that the technology skills learned were valuable such as creating "creating a spreadsheet and being aware that you can convert a spreadsheet into different types of files".

Overall, teachers seemed confident that their students had learned a great deal and benefited from the project. N.D. said that, "not only have their computer skills improved but their total awareness of the environment. It was new to them". He overheard his students saying, "I have learned more in this study than any of the current things we are

doing in school". His principal in a faculty meeting recognized N.D. for his work and a fellow teacher whose child was in his class thanked him saying that her child had learned more in his class than any of the other classes at the school. Carolyn felt that the project addressed many learning styles and observed that some students who were strong academically struggled with the computer component while others who were not as good academically were very successful at using GIS.

Question Four: How did the two units compare and what do you like or think could be changed about them?

N.D. compared the CITYgreen GIS and MOSS units. He said that the CITYgreen GIS unit was more focused on certain aspects of the school whereas he felt that with the MOSS unit "you could take that project anywhere you want and use it". He felt that the CITYgreen GIS unit was easier than the MOSS unit, which was more involved, because CITYgreen GIS had certain standardized steps that you followed. Even so he was very uncomfortable with his understanding of the models used in the CITYgreen GIS unit.

Carolyn and Pat said that next time they did the MOSS unit that they would provide more detailed computer instructions for the students. Pat explained, "Some students lacked basic computer skills and they could only retain the last step. They forgot very easily and we found that what we really needed to do was to give them a step-by-step sheet of what needed to be done in order. They had to learn how to manage their files because they kept loosing things". Carolyn said that she would "pick a definite time frame next time and stick to it". She would move more quickly in getting the data collected outside. Carolyn explained that "Next time I will have a better feel for how much time it takes to collect the data and I will give the kids some additional tips and suggestions".

Overall the teachers were very positive about the MOSS and CITYgreen GIS units. They were excited about the possibilities for repeating the units next year at their schools. During the course of the units they had developed instructions, timelines, and rubrics for their students to help manage the projects.

Question Five: What limitations or barriers have you encountered when using GIS in your school?

All the teachers reported that getting into the school's computer lab regularly was a problem. N.D. explained, "We are competing with other teachers in the school for the lab. Sometimes the lab is booked for weeks because of computer testing or teacher training. This can be frustrating. It depends on money and space". They also explained that some of the students lacked basic computer skills, which made it more difficult. Carolyn and Pat at Leesville Middle school reported that there were networking issues that had to be resolved at their school. All teachers agreed that thinking about how the students will access and save their work is an important first step before beginning this type of unit.

Question Six: What future plans if any do you have for using GIS in your school?

Carolyn said that even though the MOSS unit met several of her science objectives such as measurement, collecting and analyzing scientific data, and designing and following procedures, that it is difficult to squeeze everything in that she is required to teach during the school year. However, she continued to say that she planned to repeat the MOSS unit next year and would also like to try the CITYgreen GIS unit.

N.D. expressed concern that the MOSS and CITYgreen GIS units were an add-on to his existing biotechnology elective curriculum. He said that he would like "to fit them

better into his curriculum". However, he said that he planned to repeat the units next year also. He also expressed interest in designing other GIS related units for his class.

Pat, the media specialist at Leesville Middle, said that she planned to try other GIS units with other teachers in the school. She said, "There is a wonderful GIS unit that I want to use with the 8th grade social studies classes on the Underground Railroad, you read diaries and build a route". She also explained that she wanted to try some lessons using global positioning systems. Next year, Pat and Carolyn are planning a project in which students will create a school-wide map of where everyone in the school was born.

These teachers seem to be comfortable with using and teaching with GIS and are now able to generate other ideas about ways to incorporate GIS into their curriculum.

Question Seven: Describe how you used ADD EVENT THEME in the study site project.

Pat was able to accurately describe all of the steps necessary to complete the Add Event Theme procedure using GIS. Carolyn was also able to describe the steps accurately even though she expressed that, "I need my cheat sheet. I get confused because there are so many steps. If I have it written down then I can follow it". N.D. was also able to describe all the steps except for one but he too expressed that he needed his notes in order to recall all of the steps accurately. These responses emphasize the importance of detailed and accurate computer directions for specific GIS procedures for teachers so that they are more comfortable with using the GIS software.

Question Eight: What new science concepts did you learn, if any, from teaching the MOSS or CITYgreen GIS unit?

Carolyn said that she learned more about her students than new science concepts. She indicated that:

> "I learned the way kids interact with each other and how they can finish a long-term project. They were so good about sharing what they found with each other. Maybe we needed to have a little more show and tell time outside. I think that this project has led me to be more open ended in what I do with kids and not have them do just 1, 2, 3, which they are accustomed too. They can make the assignment, make the project and do what they want to do. They need to be given a chance to come up with their own ideas".

Pat and N.D. said that they learned how to take data from the field and put all the pieces together to make a whole. Pat said that she realized that the students had to:

> "Come up with a problem question and decide what data to collect, and then make sure the data you collected is representative of what you want it to show. It was hard for them because they had never done anything like this before. I saw little light bulbs go off when the connections hit home. I think it was good because it really made them think and come up with a question and then figure out a way to solve it, which normally the experiments were all laid out for them. What I liked about this is that we did not know what we were going to get. We learned right along with them. I found that students needed as much time to reflect on what they learned as teachers do".

N.D. said that he learned how to use the computer to help him solve problems. He learned from the CITYgreen GIS program that impervious surfaces should be restricted around a school and an environment more like a park should be created. He also learned the

relationship between roof color or albedo and energy costs. Finally he realized how the pond impacted the organisms found in his MOSS study site. He was surprised by the quality of the water and the great number of different living things that it supported. He said, "When you are in college you only learn it from a textbook but now you are seeing it. It is not theoretical but practical. It teaches you a lot about the environment and how you should take care of it".

Question Nine: What three new relationships/information did you learn as a result of these GIS applications overall?

Pat said that she felt the project, "really opened up a lot of doors to the students' thinking and changed their preconceived notions because at their age they are really not aware of the outside environment". She remarked that she learned how to identify pine trees, use a field guide, and where insects lived. She did not know that animals had certain patterns of movement. She was also interested in the soil and how temperature changes with soil depth.

Carolyn was interested in the impact that the new construction would have on the school environment. She wanted to try and add other plants and wildflowers to her study area and also bird feeders so that she could compare this year's class data with next year's data.

N.D. said that he was interested in what types of nesting birds he would find in what types of trees. He was fascinated by all of the different types of animals they found in the pond. He was also disappointed that more animals were not found in the study site itself, which was mostly hard packed clay from foot traffic. He said that, "I liked the MOSS unit

because it is flexible and innovative. The students liked collecting and processing their own data and coming to their own questions and answers. I am learning a lot".

The sociocultural model used in the MOSS/CITYgreen GIS workshop and the follow-up visits were successful in increasing teacher confidence and use of GIS in classroom instruction (Stubbs, 2003). It is important that GIS curricula easily fit into the existing curricular requirements and that teachers are comfortable and full understand the models used by the CITYgreen GIS program. Preservice teachers as well as beginning and experienced teachers can teach with GIS. In fact, GIS may be a way to help teachers gain "technological knowledge" so that they can teach *with* technology in their classrooms.

Results obtained from the quantitative and qualitative analyses provide evidence to support the use of GIS in schools to enhance middle school students' and teachers' understandings of environmental content. Overall the CITYgreen GIS comparison group was able to learn the environmental content better than the experimental MOSS group. The lab report scores were not significantly different for either group. Significant differences between the Leesville Middle MOSS group and the Carrington Middle MOSS group scores and the absence of a comparison group at Leesville Middle led to additional analyses between the Carrington Middle MOSS group and the Carrington Middle CITYgreen GIS comparison group.

The experimental group’s quiz scores were significantly higher than the comparison group; however, when considering only Carrington Middle school students, the comparison group’s quiz scores were significantly higher than the experimental group. The comparison group at Carrington Middle scored significantly better on the unit test when compared to

the Carrington Middle MOSS group. The comparison groups scored significantly higher on the individual conclusions but no significant differences were found in the lab report scores. The experimental group scored significantly higher on the GIS analysis. Sex, shop class, and computer games were significantly different when compared to spatial reasoning scores. Students who scored higher on the spatial reasoning test also scored significantly higher on the unit test.

Qualitative data further identified the environmental learning for teachers and students with GIS. Even though the CITYgreen GIS students seemed to understand the environmental content better, the MOSS students better understood how to use GIS to analyze problem questions. All students' problem identification skills and problem-solving abilities improved, even though the MOSS group asked more questions than the CITYgreen GIS group. Both groups were surprised by what they found outside their school campuses. Students said that the GIS curricula were different than what they normally did in science because of the in-depth investigation of problem questions to which there were no definitive answers. Students had previous ideas that were tested and often disproved by their results. They began to understand the connections between the different components in the environment.

Overall a mean score of 3.5 or a rating of often was reported by teachers regarding GIS implementation in their classrooms. Seventy-five percent of the teachers in the workshop reported using GIS in their teaching with twenty-five percent reporting using it little or none at all. There was no significant effect of the LSI or SES on spatial reasoning test score for teachers. There was a significant effect of the number of years of teaching

experience on the spatial reasoning test. No significant effect was found by the GIS User Questionnaire rating on the number of years of teaching. Conclusions and recommendations based on these results are presented in Chapter 5.

CHAPTER 5. DISCUSSION

This study investigated the effects of using Geographic Information Systems (GIS), a new technology, on middle school students' understanding of environmental content and GIS in a constructivist classroom. Two problem-based, constructivist, inquiry-oriented GIS curricula, one called Mapping Our School Site (MOSS) and the other CITYgreen GIS (American Forests, 2000a) were used. Teachers were trained to use both of the curricula. During the implementation of the curricula, data were collected on the effectiveness of each curriculum with their students. Three factors provided the impetus for this study. The first factor was the need to explore the potential benefits of implementing current recommendations for reform in science education (National Research Council, 1996) with GIS in order to improve understanding of environmental science in middle school classrooms (Baker, 2002). The second factor was the desire to investigate possible interactions between student learning, spatial reasoning, learning styles, and the use of GIS (Kirby, 1988). The third factor involved the effectiveness of the MOSS/CITYgreen GIS professional development program on the potential use of GIS in the teachers' classrooms (Bednarz, 1999; Stubbs et al., 2002).

This chapter presents the data (detailed in Chapter 4) in relation to each of the research questions and corresponding research hypotheses as well as prior research studies. This is followed by a discussion of the limitations, recommendations for instruction and teacher education, and recommendations for future research.

The participants in this study consisted of middle and high school teachers and seventh and eighth grade middle school students in the Raleigh and Durham, North

Carolina area. Twelve teachers enrolled in a one-week summer professional development opportunity and fall follow-up session at North Carolina State University in Raleigh, NC provided some of the teacher data. Seventh and eight grade students (n=164) of three of the workshop participants in two public middle schools, one located in Raleigh, Wake County and one in Durham, Durham County provided the student data.

This study used a quasi-experimental nonequivalent comparison group design in which two experienced instructors, one a science instructor and the other a media specialist, taught five 50-minute science classes each day for six weeks using the MOSS curriculum and another experienced science teacher taught four 50-minute biotechnology elective classes each day for six weeks using the MOSS curriculum, in the fall. This constituted the experimental group. Then, the one experienced science teacher taught five 50-minute biotechnology elective classes each day for six weeks using the CITYgreen GIS curriculum the following spring. The CITYgreen GIS group was the comparison group.

Students in the experimental group (n=131) used a web-based GIS curriculum called MOSS in which students investigated the relationships between the biotic and abiotic components of the environment using a 10m by 10m study site on their school campus. Students in the comparison group (n=33) used a GIS curriculum called CITYgreen GIS in which students investigated the relationships of the trees on their school campus to other environmental components such as impervious surfaces, buildings, and air and water quality. Students in both groups used GIS to investigate the relationships between the biotic and abiotic components of the environment through inquiry-based, problem solving

curricula based on constructivism. All instructors adhered to the same schedule of activities (Appendix Q), and used identical class assignments, unit quizzes, tests, and final projects.

Profiles of the teachers' knowledge and confidence levels in the professional development program were created from surveys, presentations, Learning Styles Inventory (LSI), Spatial Experience Survey (SES), the Purdue Spatial Visualization Test: Rotations (PSVT:R) and a questionnaire (Appendix R) administered during the school year following the project. Other related variables, such as age, gender, background, and prior experience were collected during the initial workshop.

All students in the study completed the online Learning Styles Inventory (LSI), Spatial Experience Survey (SES), and Purdue Spatial Visualization Test: Rotations (PSVT:R). These scores were used to determine indicators of spatial ability and to relate these factors to an increase in student understanding of environmental content and GIS. An objective MOSS quiz (Appendix E), a CITYgreen GIS quiz (Appendix F), and a MOSS/CITYgreen test (Appendix G) were used to measure students' understandings of the environment and GIS. In addition, after the final test, each student wrote a concluding paragraph to his or her experiment using a prompt (Appendix N). Students presented their projects to their peers at the conclusion of the unit. There were significant differences in the outcomes found between the Leesville Middle students and the Carrington Middle students, which were addressed in the study. Teacher and student interviews and student presentations were used to support, clarify, and extend the quantitative findings.

The first research question examined how the MOSS students compared to the CITYgreen GIS students in their understanding of environmental content.

Research Question One: What effect does the Mapping Our School Site (MOSS) curriculum have on middle school students' learning of environmental concepts using Geographic Information Systems (GIS)?

Research Question 1a: How do MOSS students compare to CITYgreen GIS students in their understanding of environmental concepts?

Hypothesis: Students using the MOSS curriculum will show a significantly better understanding of environmental concepts as measured by quizzes, tests, written conclusions, analysis, lab reports, lab presentations, and interviews as compared to students using the CITYgreen GIS curriculum.

Multiple measures showed that overall the comparison group understood the environmental concepts significantly better than the experimental group, not supporting the original hypothesis. Similar results were found when comparing just the Carrington Middle experimental group (n= 35) and the Carrington Middle comparison group (n=33). The unit test scores for the comparison Carrington Middle group compared to that of the experimental Carrington Middle group were significantly higher. In addition, students in the comparison group scored significantly better on the individual conclusions. There were no significant differences on the lab reports, although the comparison group at Carrington Middle did score significantly higher on the quiz as compared to the experimental group at Carrington Middle. When comparing the experimental group's quizzes to the comparison group's quizzes, the opposite results were found. The experimental group scored significantly better on the quizzes. The quiz was taken two weeks after beginning the six-week units and prior knowledge of the students at Leesville Middle School could have

caused their scores to be higher. The Leesville Middle school students quiz scores (M=78%) were much higher than the Carrington Middle school MOSS group (M=53%) or the combined MOSS group (M=71%). Since the quiz only covered knowledge of basic terms such as compass, invertebrates, and scientific name, it is likely that prior knowledge was a factor in the differences in these scores.

Students ages 14-15, who all attended Carrington Middle, scored lower on the unit test, quiz, and individual written conclusion than the younger students (ages 11-12). These individual assessments relied on the assumption that the students could read and write at an eighth grade level. Since the older students were those who had been retained in school, it is probable that they had lower reading and writing abilities. Consideration should be given to alternative testing methods such as oral testing or explaining answers into a tape recorder for students who have lower reading and writing abilities.

However, the older students scored higher than the younger students on the group scores of lab report and GIS analysis. Older students may have made significant contributions to the in-depth analyses and detailed lab reports guided by peers who had better reading and writing abilities. The three teachers involved in the study noticed that classes that struggled on reading and writing assignments excelled during the GIS units. It is possible that a more visual type of instruction like GIS aided their learning. Palmer-Moloney & Bloom (2001) found that students who were classified as learning disabled frequently performed at exceptional levels when allowed to use their spatial intelligence. Spatial intelligence involves the ability to solve problems associated with navigation, using a notational system of maps, and the use of space in the visual arts (Gardner, 1993). Since

GIS is a visual representation of information, students who have learning disabilities can greatly benefit from this type of instruction. Visualizing information shows promise for helping students to integrate concepts (Ghaem et al., 1998). In addition, these findings emphasize the importance of multiple types of assessments and multiple age groupings of students in middle school classrooms. All assessments should be designed so that they accurately measure student learning, not only reading and writing ability. All students deserve the opportunity to be successful and to explain what they have learned to others.

Students received a maximum of five points if they used GIS to perform an in-depth analysis of the problem question. The experimental group scored significantly higher on the GIS analysis for both the experimental group compared to the comparison group and the experimental group at Carrington Middle compared to the comparison group at Carrington Middle. The CITYgreen GIS program used predetermined formulas so students did not need to go beyond the use of data organization and simple queries to answer their individual problem questions. The MOSS curriculum does not provide predetermined formulas and students used the GIS program to solve their own problem questions. This encouraged students to use the full analysis capabilities of the program. Teachers and other students worked together to solve individual problem questions, which increased motivation among the students and teachers. MOSS is like painting your own picture; there are many ways it can be done and students seemed to learn how to use GIS creatively.

Qualitative data obtained from student interviews supported these findings. Overall the comparison group was able to answer all of the environmental content questions asked during the interview whereas the experimental group was able to answer only 75% of the

questions correctly. However, the MOSS experimental group answered the GIS content questions correctly more often than the CITYgreen GIS comparison group (75% compared to 53% respectively). While all students understood that GIS was used for visualizing data in layers and performing analyses, the experimental group understood better how to use GIS to solve problems and show relationships.

The CITYgreen GIS group focused on the mechanics of entering data in order to get answers to make informed decisions. It is interesting to note that when asked, "What is GIS?" the comparison group had a better overall and conceptual view of how GIS could be used. Since CITYgreen GIS allows students to use models to make future predictions using an aerial photograph of a large area, CITYgreen GIS students were able to experience ways cities use GIS to make environmental decisions. Modeling is essential to the practice of science. Using CITYgreen GIS, students created models of real world scenarios and became a part of making important environmental decisions on their school campuses. CITYgreen GIS is a way of helping students to understand how models work and their role in science. One of the comparison group students interviewed commented, "I never knew there was so much to science". CITYgreen GIS is one way that teachers can connect science content to real world experiences for students, helping them to understand the important role it plays in their everyday lives.

CITYgreen GIS focused on specific environmental content relating the benefit of trees to air and water quality and energy conservation. Students learned environmental concepts essential to understanding the models used by the program to calculate air pollution removal benefits, storm water benefits, energy savings, tree growth and wildlife

benefits. The program allowed students to participate in guided inquiry but not student-directed inquiry nor student research (Bonnstetter, 1998). The MOSS students, on the other hand, participated in the highest level of inquiry, student research (Bonnstetter, 1998). Since CITYgreen GIS focused more on content than process, student's performed better on the content evaluation and since MOSS focused more on process than content, students performed better on the process evaluations of asking problem questions, designing experiments and analyzing data.

CITYgreen GIS is more like tracing on the already painted picture (digitizing on the aerial photograph) rather than painting your own picture (MOSS). Your understanding of your painting relies on how well you understood the way the original picture was painted. Chen (1997) expounds on the importance of problem solvers understanding the underlying reasoning behind GIS operations. It is essential that teachers and students understand how the CITYgreen program is analyzing the data and that they take time to discuss their results in light of these understandings.

Because the CITYgreen GIS unit covered specific environmental content, teachers felt that the CITYgreen GIS unit was easier. However, the teachers did express frustration in understanding how the models worked. Models allowed students to ask questions about changes that could be made to their school, giving them answers about how that would affect their school. Therefore, students focused on modeling and making better environmental decisions. They did not understand how to design experiments and to use GIS to analyze and solve problems as well as the MOSS group. It is recommended that the MOSS curriculum include more specific environmental content on the components of the

study site such as the trees, air, and soil and that the CITYgreen GIS curriculum include the direct teaching of scientific process skills such as experimental design and data analysis.

Analysis of student presentations and interviews provide further evidence of the student learning that occurred during GIS curricular units, MOSS and CITYgreen GIS. Both groups reported that they learned how to work in groups, the importance of accurate data, that their hypotheses were often “disproved” (70% for MOSS and 58% for CITYgreen), and that their processes of problem solving and problem identification improved. These anomalies led to rich student learning. One of the teachers remarked, "I saw little light bulbs go off when the connections finally hit home"

At the conclusion of the GIS units, all students interviewed reported that they could more easily ask problem questions and explained possible ways of solving them. Problem identification is the first and most important step in problem solving. Oftentimes teachers abandon more open-ended inquiry based units because of frustration caused by problems that are either too narrow or too broad. Understanding how to solve problems will help students develop process skills, which they can transfer to other situations. The problem-solving and GIS (Figure 1) and problem-solving and inquiry-based learning (Table 3) model used in this study worked well for designing and implementing instruction using GIS in the classroom. This framework could have broad applications for teaching and learning with GIS.

Research Question Two: Is there a correlation between student learning and spatial reasoning, learning styles, and the use of Geographic Information Systems (GIS)?

A subset four research questions was posed to examine if related abilities could improve understanding of GIS. The hypotheses and the questions are discussed below.

Hypothesis: Students who are visual learners and have more significant predictors on the SES will be more successful on the PSVT:R test and will have a better understanding of GIS as measured by the quiz, unit test, and individual conclusions than those who have low PSVT:R scores.

Research Question 2a. Which background experiences, such as academic courses (geometry, drafting classes), non-academic activities (toys, computer games), and sports are significant predictors of success on the Purdue Spatial Visualization Test: Rotations (PSVT:R) for teachers and middle school students using the Mapping Our School Site (MOSS) curriculum and the comparison CITYgreen GIS curriculum?

Of the possible predictors of spatial ability which included sex, GIS experience, learning style as reported on the LSI, and factors on the SES such as handedness, academic courses (geometry, shop class, 3-D courses), non-academic activities (toys, computer games), and sports activities it was found that only Shop class and computer games showed a significant effect on the spatial reasoning test.

The more computer games played, the higher the spatial reasoning score. Most students (60%) seemed to play computer games weekly or daily. Tarte (1990) and Parolini (1994) also found that computer game use had a positive significant effect on spatial reasoning scores. Playing computer games successfully requires students to operate in a

three dimensional space and to repetitively orient themselves correctly within that space. It is not surprising that consistent exposure on a weekly or daily basis may improve students' spatial reasoning abilities. Ways to provide similar experiences in an educational environment is a challenge for educators. Using GIS in the classroom is one way that this can be accomplished. Qualitative data from this study showed that students used computers at home, yet according to Horizon Research (2000), the use of computers in science instruction has changed little from 1977 to 2000 with fewer than 10 percent of science lessons including students using computers. All but one student interviewed said they never use computers in their science classes. Yet, students said they enjoyed using the computer and the GIS software. Problem-solving, inquiry-based units such as CITYgreen GIS and MOSS are a way of incorporating computer use that focuses on spatial reasoning into the science classroom. These units may be a way to help teachers gain, "technological knowledge" so that they are comfortable teaching with new technologies such as GIS.

Learning Style, school, sports, age, or geometry classes, and 3-D classes did not show a significant impact on spatial reasoning test scores. In Parolini's study (1994) and Deno's study (1995), experiences in academic courses such as geometry, shop classes, and 3-D courses, had a significant effect on spatial reasoning test scores. In this study, the fewer shop classes taken, the higher the spatial reasoning test scores. Most students had not yet taken or had only taken one shop class (95%). Middle school students have not yet had the opportunity to be involved in these courses. The SES needs to be revised to better reflect experiences that are available to middle school students such as involvement in art and other construction projects such as model building, car or bicycle repair, and building

hobby train sets. In addition, increased exposure to 3-D courses for students at an earlier age needs to be considered in schools. Some possibilities in science include building bridges, solar cars, how machines work, and the study of art and form in science.

Also unlike Parolini's study (1994) and Deno's study (1995), spatial reasoning scores were not significantly affected by playing with construction toys. Surprisingly, most students (M=3) played with three or more of the five construction toys listed. Other newer construction toys such as Kinnex© should be added to the list to better reflect the type of construction toys to which students might have been exposed. More research needs to be done on the importance of children playing with construction toys at an early age on spatial reasoning ability. Idle et al. (1993) found that parents were choosing construction-type toys more for boys as compared to females. Since males and females had played with construction toys by middle school, more research needs to be done to determine the importance of early play with these types of toys on spatial reasoning ability.

Agreeing with Parolini's study (1994) and Deno's study (1995), spatial reasoning scores were not significantly affected by actively participating in sports. Since most students on the survey participated in a variety of sports and after school activities such as soccer, dance, and gymnastics, it may be better to study those students who are active compared to those students who are inactive in sports to determine if sports significantly affects spatial reasoning ability. This question may need to be changed or replaced on future spatial experience surveys.

There were no significant effects of the factors on the SES such as academic courses (geometry, drafting classes), non-academic activities (toys, computer games), and sports on

spatial reasoning scores for the twelve teachers in the study. It is possible that the sample size was not large enough to adequately test the hypothesis. In the future, the SES and spatial reasoning test should be administered to a larger group of teachers.

Research Question 2b. Does gender interact with various success predictors of spatial reasoning?

Males did score significantly higher than females on the spatial reasoning test. This agrees with Parolini (1996) and Kimura (1992), Gimmestad (1990), and Baenninger & Newcombe's (1989), who found that males performed better than females on spatial tasks. This finding is also supported by brain research that has shown that there are neurological differences in the male and female brains (Nordvik & Amponsah, 1998). Kimura (1992) explained that men's brains have been found to be more sequential compared to women who are more global in their thinking. Men are better at mathematical reasoning and navigation while women use landmarks to navigate and are better at mathematical calculations. As a result of these differences, a revised spatial reasoning test (Branoff, 2000) in which the coordinate axis were labeled to eliminate gender differences was used in this study. Branoff (2000) found that by labeling the coordinate axes, he eliminated male and female differences in college students. Even though Branoff's (1998; 1999) revised PSVT: R was used, there were still male and female differences in the spatial reasoning test scores. Further research needs to be conducted in the reliability and validity of using this test for middle school students. Since the mean score on the spatial reasoning test was a 41%, possibly more items that were of medium difficulty could be included with fewer test items of maximum difficulty. However, since one student did score a 97% on the test and

eight students scored in the 80% range, consideration would need to be given to students who scored high on the test.

Ben-Chaim et al. (1988) found that the optimal time for teaching spatial visualization tasks was in the seventh grade before the increasing gap between boys and girls begins between the seventh and eight grades. Perhaps, psychology and geography need to build a new theory of spatial thinking and action (Blaut, 1999). Teaching with GIS in middle schools may be a way of decreasing the gap in spatial reasoning ability between girls and boys and exposing all students to more spatial related tasks.

Research Question 2c. Does learning style correlate with the success predictors of spatial reasoning?

Learning style did not significantly affect any of the predictors of spatial reasoning including the spatial reasoning test for students and teachers. Students were evenly distributed between the three possible modes of learning with 31% identified as auditory, 35% kinesthetic, and 34% visual learners. However, eleven of the twelve teachers identified themselves as visual learners. It is possible that GIS appeals to teachers who are visual learners or it could be that teachers were predisposed to choose the visual responses. A larger sample size of teachers is needed to determine if there is a relationship between spatial reasoning and learning style.

The findings of this study agree with Kirby, Moore, & Schofield's (1988) study in which 350 adults completed a learning styles inventory and a spatial reasoning test. They found that there was a lack of relationship between visual learning style and spatial reasoning. Learning styles may be highly variable in individuals and more dependent on

the specific learning task or strategy than on the individual's preferences. These findings emphasize that care should be given in creating associations between the use of GIS in instruction and the assumption that it will provide success for students whose are visual learners. The interdisciplinary nature of instruction when using GIS in the classroom and the possibility that it appeals to all types of learning styles may be a more appropriate assumption.

Research Question 2d. Is there a relationship between learning style and the success predictors and the learning of the GIS curricula (MOSS and/or CITYgreen GIS)?

Consideration was given to the possibility that if an individual possessed a higher spatial reasoning ability as shown by the spatial reasoning test, then he or she would possibly score better on the unit test, quiz and/or the written conclusion. Lab reports and analyses were not considered because these were group scores. Learning style or a visual preference for learning did not significantly affect the spatial reasoning test score. There was no significant difference between the spatial reasoning test score for the MOSS and CITYgreen GIS students or their conclusion scores. There was a significant difference between the spatial reasoning test scores and the unit tests and quiz scores. It might be concluded that students who had better spatial reasoning ability, also scored higher on the unit tests and quizzes and therefore were better able to learn environmental content. This agrees with Pallrand and Seeber's (1984) findings that spatial ability enhances a student's ability to make sense of data and with Clements et al. (1997), who stated that spatial ability is linked to logical and scientific reasoning and mathematics competencies. This reemphasizes the importance of providing opportunities for students to engage in spatial

reasoning tasks so that skills can be developed that are important to success in science and mathematics (Thompson et al., 1997). Teaching with GIS may be one way to provide more spatial reasoning tasks in schools, providing an opportunity to improve the spatial reasoning skills of students.

Research Question Three: What is the likelihood of teachers implementing GIS in their classrooms after the weeklong GIS workshop and fall follow-up session?

Research Question 3a. To what degree are the GIS workshop teachers using GIS for classroom instruction the school year after the workshop?

Hypothesis: At least half the teachers will demonstrate continued use of GIS in their classrooms for instruction the school year after the MOSS/CITYgreen GIS workshop.

Twelve teachers participated in a one-week MOSS/CITYgreen GIS workshop and fall follow-up session. Teachers were supported as they implemented the GIS curricula the following school year. At the end of the next school year or two years after the summer workshop, teachers completed a 17-item questionnaire regarding the degree of GIS implementation in their classroom teaching. Seventy-five percent of the teachers in the workshop reported using GIS in their teaching with an overall mean score of 3.5 ("often"), indicating continued use. This is better than the expected 50% stated in the hypothesis.

Baker (2002) identified that it was critical for teachers to be instructed not only in how to teach with GIS, but also in the pedagogy of inquiry and problem solving strategies. Kerski (2000) in a national survey found that 50% of teachers owning the GIS software were not using it at all and only 20% had used it for more than one class or one lesson. The sociocultural model used in this workshop and follow-up visits were successful in

increasing teachers' confidence and use of GIS in classroom instruction (Stubbs, 2003). These techniques included:

- Discussing the connections between MOSS and CITYgreen GIS and their curriculum.
- Direct pedagogical instruction in how to manage students in the out-of-doors.
- Instructional techniques and classroom management strategies to use when teaching with technology.
- Development of an implementation plan (Paul & Volk, 2002).
- Incorporation of teachers who were already using this approach interacting with workshop participants (Paul & Volk, 2002).
- Establishment of a communication network for support including follow-up meetings, onsite visits, and electronic correspondence (Paul & Volk, 2002).
- Open early morning and evening lab times for extra practice during the workshop (Bernarz, 1999).
- Using scientists as a resource for teachers (Cunningham & Stubbs, 2003).
- Providing a five-step leadership model for continued teacher professional development in teaching with GIS (Stubbs, 2003).

The workshop schedule can be found in Appendix Q. Teachers, during the interviews, explained that teaching with technology required different pedagogical skills. Pierson (2001) identified that teachers need another component, technological knowledge. Educational leaders need to look beyond technology purchases and focus efforts instead on creating environments that are conducive to the continued use of technologies such as GIS

in the classroom. The MOSS/CITYgreen GIS workshops and follow-up teacher support are a step toward creating such environments that support the full integration of technology into classroom practice to improve student learning (Stubbs, 2003; Stubbs et al., 2002).

The teachers also completed the spatial reasoning test, LSI, and SES. There were no significant effects noted for learning style, handedness, academic courses, non-academic courses, or sports activities. Additional background information was reported by the teachers such as years of teaching, grade level, subject taught, and areas of licensure.

There was a significant effect of years of teaching experience on spatial reasoning test score. It was found that the greater the number of years of teaching experience, the lower the spatial reasoning test scores. This agrees with McGee (1979) who found that spatial reasoning ability decreased with age. Consideration needs to be given in teacher workshops for older teachers who may have more difficulty initially learning how to use GIS. Extra assistance or peer mentoring was found to be a valuable strategy for those who were having more difficulty understanding and using the technology.

An ANOVA showed that years of teaching experience had no impact on the GIS User Questionnaire ratings. Most teachers, regardless of experience or their spatial reasoning scores, can implement GIS into their classroom instruction. Bednarz & Ludwig (1997) suggested that preservice teachers receive training in the use of GIS in the classroom. These findings conclude that it is possible for teachers with less experience as well as those with more experience, to incorporate GIS into their classroom instruction.

Teachers were able to install the software on the computers at their school, had confidence in teaching with GIS, had presented GIS at conferences and had even taught a

course using GIS in their schools to a great extent. This significantly contrasts to the mean confidence rating of "little" that was reported by teachers at the end of the MOSS/CITYgreen GIS summer workshop. It seems that continued support through e-mail and site visits is very important to the full implementation of GIS in the classroom (Bednarz, 1999; Stubbs et al., 2002).

Teachers reported that they used CITYgreen GIS "little to none" in the classroom, did not use GIS as part of an award, or attend a GIS college course. Though teachers often created their own lessons, units, and projects, they reported "little to none" of their own GIS curriculum development. Time to learn and implement GIS in the classroom has been identified as a barrier for teachers (Bednarz, 2000). It can be concluded that the developing of inquiry-based problem solving curricula such as MOSS and CITYgreen GIS as well as teacher workshops are very important to the implementation of GIS in the classroom (Kerski, 2000; Stubbs, 1999).

Even though teachers identified that CITYgreen GIS was easier to use, it was used "little to none" in the classroom the following years. Teachers expressed that MOSS was more flexible and that since it focused on experimental design and measurement, it fit well into their existing curriculum. Pat said, “It touches on just about everything that is taught in science in middle school. It is just how creative you want to be”. Based on teacher comments and scores, it is important for GIS curriculum to easily fit into the existing curriculum in schools. These connections should be discussed during the teacher workshop (Bednarz & Ludwig, 1997).

CONNECTIONS TO THE LITERATURE

One of the factors providing motivation for the study was recommended reforms in science education. The *National Science Education Standards* encourage activities that require students to ask and answer research questions and to engage in scientific investigations like the ones described in this study. The *National Science Education Standards* (National Research Council, 1996) state that the major goal of science education is to produce students who are scientifically literate and technologically informed. For students this type of learning should include inquiry, problem identification and solving, modeling, reasoning, creating connections, communication, technology use, and real-world mathematics.

Various researchers have suggested a constructivist environment to engage students in inquiry learning (Baker, 2002; Hatano & Inagaki, 1991; Rohler & Cantlon, 1997). Students must construct connections between different types of representations of data in order to create links that will help them to draw meaningful conclusions. In the MOSS and CITYgreen GIS units, students did create connections by analyzing and representing data in a variety of ways in order to answer individual problem questions.

By solving problems repeatedly using the steps of skillful problem solving (Swartz, 1994), students reported that their problem identification and problem solving skills improved. Audet and Abegg (1996) also found in a pilot study that learning GIS helped high school students develop problem-solving abilities. Asking questions about objects, organisms, and events in the environment is another goal of the *National Science Education*

Standards (p. 122). MOSS and CITYgreen GIS are based on environmental content that address this goal.

One of the findings of this study was that the MOSS and CITYgreen GIS curricula were different from what students normally did in science class. Students reported that the GIS units were more in-depth, required using the computer, involved more mathematics, and took place outside. These activities focused on the goals of the *National Science Education Standards* in which students engaged in in-depth investigations, worked in groups to design and conduct experiments, developed explanations, and presented their findings to others. Teachers also commented that they had never done an open-ended project like this before in which they were learning with their students. "It was not out of a textbook", said one teacher. The MOSS and CITYgreen GIS curricula provided examples of how to teach science using technology and mathematics in an inquiry-based problem solving approach as suggested by the *National Science Education Standards.*

Meyer, Butterick, Olkin, & Zack (1999) suggested that GIS could be a tool to enhance teaching methods, provide better content delivery than textbooks, and prepare students for uses of spatial technologies later in life. Teachers reported that their computer skills improved as well as their students' technology skills, especially the use of spreadsheets and file management. GIS can assist in the of teaching basic computer literacy while students are learning science content (Fitzpatrick & Maguire, 2001).

GIS may be able to play an important role in educational reform because it can help promote change and growth for skill development, classroom organization, instructional methodology, curricular content, and community participation, all at the same time

(Fitzpatrick & Maguire, 2001). Teachers who integrate GIS into their curriculum have noticed a shift from a more didactic method of instruction to a more student-centered inquiry approach (Audet & Paris, 1996; Bednarz, 1999, 2000). Technology can bring us all closer to each other as we try to understand the changing relationships between people, places, and the environment. It creates a common ground, a common language (Fitzpatrick & Maguire, 2001).

LIMITATIONS

The interpretations of the results are limited by certain factors. This section includes a discussion of the questions related to internal and external validity of the findings and the efforts that were made to control the influences of these factors.

Internal Validity. Since two teachers and their students were from Leesville Middle School in Wake County and one teacher was from Carrington Middle School in Durham County, there was a possibility that preexisting differences between the groups rather than the experimental treatment explained the findings. The use of a comparison group at Carrington Middle helped control the differences between the two groups. However, from the results, it appears that preexisting differences did exist between the groups. Therefore, the experimental group and comparison group's results were analyzed for significant differences and the Carrington Middle experimental group and the Carrington Middle comparison group was also analyzed for significant differences. The results were then compared to each other. This helped to further validate the findings of this study. If a comparison group at Leesville Middle could have been established, it would have further

helped to validate the findings of the study and to identify the differences between the groups of students.

None of the students from any of the groups reported being familiar with MOSS, CITYgreen, or GIS. None of the students had ever taken the spatial reasoning test, LSI, or SES previously. Similar laboratory equipment was used at each school. All students used a computer lab of similar computers at each school to complete the GIS analyses. The instructors were careful not to encourage any sense of competition between the different class periods of students and no student that completed the MOSS unit in the fall completed the CITYgreen GIS unit in the spring.

The researcher could not control the effects of day and time. However, all classes met on the same day of the week at the same time each day for 50 minutes. In an effort to control for instructor differences, the instructors carefully followed the same schedule and used the same instructions, GIS software, homework assignments, rubrics, quizzes, and tests. The teachers in this study attended a one-week MOSS/CITYgreen GIS workshop and follow-up session and taught the MOSS unit that school year. The following school year, during the study, they were teaching the MOSS unit a second time. Only N.D. had taught the CITYgreen GIS unit the previous school year before the study. The software needed for this study was installed on the computers at the school before beginning the study. The researcher observed all the classes minimally on a weekly basis and it did not appear that the experimental or the comparison group classes were treated differently relative to instructions or expectations.

External Validity. The use of intact classes limits the generalizability of the study to other populations or settings. The findings of this study can only be applied to similar middle school students with similar backgrounds. Also a relatively small population of students (n=33) was considered for the CITYgreen GIS comparison group. There were only twelve teachers involved in the MOSS/CITYgreen GIS teacher workshop.

At the beginning of the experiment the researcher observed a certain degree of novelty associated with going outside to collect data and using a computer and GIS to analyze the information in order to answer problem questions. However, by the end of the study, there was no evidence of a novelty effect.

The researcher carefully followed an interview guide when collecting the qualitative data. While it is possible that researcher bias or expectations may have influenced the behavior of the subjects during the interviews, care was taken to make each individual feel comfortable before beginning and during the interviews. Interviewees were randomly selected and they were all volunteers. No one was forced to participate in the interviews.

A few days of classroom instruction were lost from the MOSS group and the CITYgreen GIS group due to very cold winter weather and ice and snowstorms. However, students did not seem to be affected by cooler temperatures and continued to work outside collecting the data.

The researcher choose to use ArcView© and CITYgreen GIS, an extension to ArcView© for this study. The MOSS curriculum was online for teachers and students. The conclusions of this study are only applicable as measured by the particular software and instruments used in this study.

RECOMMENDATIONS FOR STUDENT INSTRUCTION

Reform documents such as the *National Science Education Standards*, the *Standards for Technological Literacy*, and the *National Council of Teachers of Mathematics Standards* advocate an increased emphasis on real-world problem solving in which inquiry-based learning and thinking occur, using technology as both a tool and a goal of learning. The findings of this study indicated that using the inquiry-based problem solving units of MOSS and CITYgreen GIS to teach environmental content, relating concepts to real world experiences, improved students' problem identification and problem solving, provided instruction in technology skills, and allowed students to engage in open-ended experimentation of their own design.

The effectiveness of the activities indicates the importance of inquiry-based, problem solving teaching and learning that allows students to gather, analyze, and interpret real-world data and to create connections with reflection among the various types of information. The findings also suggest that in order to promote conceptual change, units that use GIS should focus on content rather than "learning the GIS software", follow a progression from basic to more complicated skills, be generic and not site specific, and involve student communication with connections to realistic data and issues (Sharpe & Best, 2001). There is a balance between providing step-by-step GIS directions and at the same time not creating barriers to rich data analysis and exploration. It is suggested by this study that step-by-step procedural experiment and GIS instructions be provided in the beginning of a unit with a progressive decrease in instruction as students begin to solve their own problem questions. There is a danger when using GIS in content instruction that

it can become little more than an electronic textbook in which interactive maps are used for students to search for predetermined patterns and answers. The MOSS/CITYgreen GIS curricula are examples of active learning materials that use open-ended inquiry and fully integrate mathematics and technology into the science classroom. This study suggests that GIS curricula should be developed that encourages open-ended inquiry.

From a constructivist perspective, students rely on their prior knowledge and past experiences to construct their own meanings. Throughout this investigation, students were observed to possess and rely on their own preconceptions. For example, students had difficulty understanding how to use a field guide, how to measure tree height using a clinometer and how to measure the diameter breast height of trees. Students looked through the straw of the clinometer instead of looking down the top of the straw to find the top of the tree and when measuring diameter breast height they held the tape measure end to end instead of at the zero point. Student's prior learning regarding how to use the instruments required a reteaching of these concepts.

While students had little trouble understanding how to use the grid or aerial photograph to determine locations, students had a great deal of trouble understanding how to design data tables, relating the outside coordinates to the columns and rows in the table. Misunderstandings regarding data table design and how to organize the data for analysis in order to answer problem questions proved to be a challenge for students. Since data tables are usually already designed for students when they do experiments, it is important that teachers allow students to design their own tables and to relate data collection to data analysis and conclusions when performing science experiments.

It was found in this study that overall, the students in the CITYgreen GIS group learned the environmental content better than the students in the MOSS group, but that the students in the MOSS group better understood GIS and how to use it to analyze data. The MOSS students focused more on relationships and ended up with more questions than when they began the experiment. The CITYgreen GIS students felt like they had the answers that could be used to make more informed environmental decisions. The CITYgreen GIS unit allows for "what if" questions associated with models that can show change over time (McGarigal & Romme, 2003). Based on these findings it is recommended that an instructor begin their year with the CITYgreen GIS unit, which is focused on the topic of trees and their specific relationships to the environment and provides students with a better overall understanding of their environment. The following spring allow students to complete the MOSS unit in which they reinforce their understanding of the environment but also extend this understanding to include their own experimental design and a more open-ended use of GIS to solve problem questions. Instruction should be provided for students that allow them to explore the outside environment, especially when studying environmental concepts. This not only increases understanding of the concepts but it also creates relevance and interest for students (Cunningham & Stubbs, 2003).

CITYgreen GIS allows students to participate in guided inquiry (Bonnstetter, 1998). If an instructor teaches CITYgreen GIS in the fall, they are helping students build skills they will be able to use to create their own projects using MOSS in the spring. Students must construct connections between different types and representations of data in order to create links that will help them to draw meaningful conclusions. There is a growing body

of evidence that technology, when used in a constructivist environment, can help students to solve problems more effectively (Cates, 2000). Audet and Abegg (1996) also found that a gradual passage through several identifiable intermediate stages of procedural knowledge was important when using GIS to solve problems. The CITYgreen GIS and MOSS units are examples of classroom applications of GIS that address how to identify stages of knowledge levels and progressively guide students from a lower level to a higher level of abstraction as they learn environmental content.

It is also recommended that instructors identify environmental content involved in these units and that this content be purposefully integrated into the units. A variety of resources should be used including primary and secondary resources, various textbooks and newspapers, and electronic resources such as the Internet.

The findings of this study also indicate that students benefit from an interactive and exploratory environment. Therefore, a final recommendation for instruction is that collaborative work using cooperative learning strategies be encouraged when students use GIS and that there be a balance between "inside work" and "outside work". This helped to motivate the GIS data entry and students understood the connection between the environmental data they were collecting and its representation on the computer. If they had questions about their data when they were using GIS to analyze it, they could go outside and double check their findings. The teachers identified this strategy to be important to the success of these units.

Students identified in interviews that their projects were easier to do when everyone worked together. The CITYgreen GIS and MOSS units encouraged collaborative work by

placing students in lab groups to perform their experiments. Students completed one analysis and one lab report, presenting their findings to the class as a group at the conclusion of the units. The interactive maps easily illustrated the students' findings as they used the GIS program to explain their results. GIS provided a dynamic medium for communication (Thompson, Alibrandi, & Hagevik, 2000).

RECOMMENDATIONS FOR TEACHER INSTRUCTION

Research shows barriers do exist to successful implementation of GIS in classrooms. Teachers must change from teacher-centered to more student-centered teaching approaches such as problem or project-based learning. Teachers need time to learn the software and to practice how to use it (Bednarz, 1999) and support is needed as teachers continue to integrate GIS and other spatial technologies into their curriculum (Environmental Systems Research Institute, 1997; McWillimas & Rooney, 1997). Teachers who integrate GIS into their curriculum have noticed their own shift from a more didactic method of instruction to a more student-centered inquiry approach (Audet & Paris, 1996; Bednarz, 1999, 2000).

Technology needs persist in being a barrier to using GIS in the classroom. While schools do have more computers available to them for student use, there is more of a demand for the use of these computers. District and administrative support are very important when incorporating GIS into classroom instruction. Installation and maintenance of the software on the network, downloading data from the Internet, and students saving the data and projects they have created on the computers are all issues that need to be addressed

when using GIS in schools. In addition, printing student maps, especially in color, can be an added difficulty.

Stubbs et al. (1999) identified future GIS professional development efforts in K-12 education as (1) establishing professional development teams for preparing teachers, (2) supporting teachers in data quality and sharing, (3) providing statewide databases for student projects, and (4) providing leadership and mentoring for new teachers. Kerski (2000) called for the development of educationally based curricular materials that allow students to perform spatial analyses and problem solving techniques and training for teachers in how to use this curriculum in their classrooms. The MOSS/CITYgreen GIS workshop and associated curricula helped address the need for professional development of teachers, support for teachers, and the mentoring of teachers as they implemented the units in their classrooms.

The MOSS/CITYgreen GIS workshop and follow-up session were based on a model of professional development that incorporates a sociocultural or social constructivist perspective of professional development (Howe & Stubbs, 2003a). The focus of the workshop was to improve science teacher's knowledge, the teaching of science, and to empower the teachers as individuals to implement the GIS curricula in their schools. The workshop included inquiry by generating questions, designing, conducting field studies, communicating findings, laboratory-based investigations, scientists as experts, and the development of an implementation plan. Participants were given time to discuss pedagogy, participate in local field-based experiences, attend open evening lab times for additional practice, and to develop an implementation plan for their school. Continued teacher

support was provided through online communications and school visits as well as ongoing training, and technical assistance. The teachers also received the software and supplies needed to complete the units in their schools.

The findings from this study show that the teacher workshop was successful in empowering teachers to implement the MOSS/CITYgreen GIS curricula in their schools. An important component to the success of this workshop was the ongoing continued support for teachers throughout the school year. The workshop was successful in helping teachers to implement a more student-directed open-ended approach to classroom instruction while at the same time increasing their technology skills. Teachers also learned a great deal of environmental content and experimental design as they completed the units with their students. In addition, teachers learned about their students. They experienced how students could work together to finish a long-term project, how they could come up with their own ideas, and realized how important discussion and reflections were in relation to student learning. It is very important that professional development for teachers using GIS incorporate a social constructivist model in which teachers build upon their own understandings and then share these understandings with their students through an inquiry based problem-solving approach (Howe & Stubbs, 2003b).

RECOMMENDATIONS FOR FUTURE RESEARCH

One of the factors providing motivation for the current study was the need to explore the potential benefits of using GIS to understand environmental science content in middle school classrooms. At the present time, research studies pertaining to the uses of GIS in classrooms are at the initial stage of inquiry. The majority of studies related to GIS

in schools have compared achievement and/or attitudes of students using GIS to those not using GIS. There have been few studies that include the professional development of teachers and their implementation of GIS in the classroom with their students. There have been no studies that compare the use of two different GIS units and that address the best uses of GIS in classrooms. It is recommended that the present study be expanded and replicated in more schools with a larger sample size of teachers and that it include a larger comparison group. Additional comparison studies need to be done that compare a more direct approach of using GIS in classroom instruction to a more open-ended approach to determine the possible impacts on student learning. A longitudinal study in which different approaches to MOSS and CITYgreen GIS implementation and subsequent impacts on student learning in science and possibly other subject areas would be valuable.

More research needs to be conducted regarding the GIS problem-solving, inquiry-based conceptual model proposed in this study. While effective in these units, research into the applicability of teaching other GIS courses using this model should be investigated. As web based GIS becomes more prevalent, investigations of the use of this model to better communicate information in order to make informed community decisions would be interesting. The MOSS and CITYgreen GIS units have been taught to students from grades six to graduate school and have broad applications to many different age groups. An investigation into the use and effectiveness of these units at other age levels and comparisons between these applications would create a deeper understanding of the uses of GIS for instruction.

Teachers who integrate GIS into their curriculum have noticed their own shift from a more didactic method of instruction to a more student-centered inquiry approach (Audet & Paris, 1996; Bednarz, 1999, 2000). Since GIS encourages collaboration and communication, it is possible that greater student conversation that is more indirect could translate to increased student learning (Hagevik, 2003a). Teachers could be studied over time to determine how their teaching practices, beliefs, and attitudes change as they incorporate GIS into their classrooms and ways this affects their students' learning.

During the open-ended inquiry, student discussion occurred outside and in the computer lab as they solved their problem questions. A study that captured these conversations and analyzed the changes in language and culture as students worked at the computer to solve scientific problems would be extremely valuable. Future studies should incorporate both quantitative and qualitative research methods. The inclusion of qualitative research methods as a complement to quantitative analysis would be particularly useful in exploring students' conversations.

Many different critical thinking skills are involved when engaging students in problem solving with GIS. An incorporation of the direct instruction of additional critical thinking skills into the instruction of the MOSS and CITYgreen GIS units would be valuable. Future studies could determine which thinking skills were most essential and the best ways for these to be integrated into instruction.

Students in the CITYgreen GIS group were assisted in their understanding by using an aerial photograph of their school campus. Conceptual understanding when using photographs of an area needs to be further studied. In addition, students in the MOSS

group created their own representation of a 10m by 10m study site. Specific spatial reasoning abilities related to three-dimensional representations compared to two dimensional representations on the computer and the best way to teach these skills needs to be further studied and explored.

It is evident that changes need to be made to the MOSS online curriculum and the CITYgreen GIS unit. From the findings of this study, the MOSS online curriculum needs to include more specific GIS directions. Content needs to be developed for the broad categories of trees, soil, animals, and insects. The CITYgreen GIS unit needs a better description and explanation of the models and their meanings and ways that they can be modified. A study comparing the students who learned the CITYgreen GIS unit in the fall and the MOSS unit in the spring to students who only studied the CITYgreen GIS unit or the MOSS unit could also help to reveal additional differences between the units. A study comparing when the units were offered, spring or fall, could increase understandings related to the best progression when teaching content and process using technology.

The inquiry-based activities could become web-based inquiry activities (WBI) in which students from different regions share their findings with each other (Bodzin & Cates, 2002). They could even engage in collaborative experiments. A comparison study using similar techniques could compare the differences in student learning between collaborative experiments with classes in different schools to those without any collaboration.

Future research is needed on different ways that GIS can be incorporated into different subject areas in schools. It would be valuable to understand when it is best to use detailed instructions during units that involve GIS. The inclusion of more mathematics use

in science instruction or an increase in the integration of subjects and its impact on student learning could be explored. Other workshops and courses could be developed for preservice and inservice teachers that incorporate the use of GIS into classroom instruction. Additionally, existing curriculum could be revised to include GIS and other technologies in instruction. Studies that advance the many ways that GIS can be used in the classroom and the impacts on teaching and learning of content and technology would be valuable.

This study should also be replicated with other GIS related technologies such as hand held computers or global positioning units. Computer probe ware could be utilized in the field for data collection. The integration of other technologies in which ease and accuracy of data collection could be increased may afford students even greater opportunity to generate and explore problem questions and solutions.

The instruments used in this study to assess learning style, spatial reasoning aptitude, and spatial reasoning ability need to be modified and studies should be conducted regarding the reliability and validity of these instruments. The effect of spatial reasoning skills and aptitudes and their impacts on student learning need to be further investigated. Others have reported that using GIS in the classroom has improved the learning of students with disabilities (Palmer-Moloney & Bloom, 2001). More research needs to be conducted to see if GIS can enhance the learning of those students who have trouble reading or writing or possibly those with other disabilities. Since students reported a wide variety of at home computer uses, a study on the impact of these skills on spatial reasoning ability and the learning of content using GIS could be studied. More studies need to be conducted on

activities such as GIS and ways that these activities can possibly improve spatial reasoning skills in students.

The emergence and incorporation of new technologies in the science classroom will play a significant role in science education in the future. GIS is an important technology that affects each of our lives everyday. Audet and Paris (1996) in a national report noted:

> "GIS has significantly enhanced teaching and learning environments by enhancing problem solving, spatial data analysis, supporting interdisciplinary connections, and motivating students. GIS will be common in tomorrow's schools and become the tool of choice for exploring spatial concepts".

This study provides two six-week GIS units that can be used to teach with GIS. Many questions still need to be investigated and just like the MOSS students there are more questions at the end of this study than at the beginning. The challenge to the science community is to provide more research that exemplifies the best ways to incorporate the teaching and learning of science with technologies such as GIS into classroom instruction in order to make learning more relevant and meaningful. Hopefully, this study will encourage others to continue this research. It is the researcher's dream that one day every school will use the power of GIS to make learning more meaningful for students.

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APPENDICES

APPENDIX A - MAPPING OUR SCHOOL SITE ONLINE CURRICULUM

M.O.S.S. Mapping Our School Site

Study Site Project Information

http://www.ncsu.edu/scilink/studysite

Getting Started	Base_Grid Shapefile base.dxf file Grid_30mtr Shapefile Grid_30mtr dxf file	Field Work Schenck Forest	Metadata
Team Directions	10 Meter Data Collection Grid (.doc) (.pdf) 30 Meter Data Collection Grid (.doc) (.pdf)	Sample Projects Complete Example Project	Evaluation
Problem Solving	ArcView Help and Hints Good ArcView Habits	Video Tutorials	Support

Leesville Middle Video Example from the NC Department of Public Instruction
Be sure to click your connection speed!

Learning Objectives

This project focuses on real world data collection techniques, documentation, and its application to GIS analyses. You will use your science skills to study and map nature by creating a data collection procedure and data sheet; adding themes of data; and using other analyses tools such as GIS to solve problems. Individually you will be

guided through the problem solving process and eventually create a visual and written representation of your conclusions. Your final project will include a hand drawn map, your GIS project with metadata, your data collection procedure and data sheet, and a written document (report) that contains a map of your conclusions.

Getting Started

In this project you will study the biotic and abiotic community interactions in a 10 meter by 10 meter study site on your school campus. Choose an interesting plot in an area that is not well traveled. Your plot should contain some variety such as trees, shrubs, ground cover, habitat for animals and could also possibly contain water, bare ground etc. It must be somewhere that is easily and legally accessible to you. You may want to consider a certain factor that interests you and then choose a study site to match that criteria.

This study represents a small area or a quadrate study. It is easy, however, to visualize each 1 meter by 1 meter square of the plot representing 100's of acres of land and the data collection becoming more relative. The first step is to measure and delineate your study site. You will be working in teams using the Survey Team directions below and the Grid (word file) (acrobat file) to record data.

Survey Team Directions
Team 1- Trees
Team 2- Abiotic factors
Team 3 - Pitfall traps
Team 4 - Animals
Team 5 - Vegetation/groundcover

The data will then be entered into ArcView and a project of your study area will be created. Each team will receive a copy of the project so that another data collection procedure can be designed and a team analysis can be completed.

Evaluation Criteria

You will submit a floppy diskette (3.5") that will contain all project materials with your GIS project and a written report (document) working with your research team. You will be graded on this project using the following evaluation criteria:

- project with metadata
- text file of your data collection procedure
- data sheet
- text file of the written document that contains a map of your conclusions
- printed out text file of written document or report
- your hand drawn map should be attached to the diskette

APPENDIX B - CITYGREEN GIS ACTIVITY

CITYgreen 4.0 Student Instructions

MAPPING YOUR GREEN COMMUNITY

Creating, analyzing, and modeling your school campus using CITYgreen and GIS

Rita Hagevik, North Carolina State University, rita_hagevik@ncsu.edu

Introduction

- Trees benefit the environment in many ways such as:
- Reduce surface water runoff and reduce the risk of flood
- Reduce soil erosion and sedimentation
- Absorb water and air pollutants
- Provide wildlife habitat
- Recreation
- Reduce energy costs and control micro-climate
- Buffer noise
- Reduce crime and lessen stress

The tree inventory that you are about to create will serve many functions. It will provide your school with essential data to maintain, protect, and plan for the future environmental and economic benefits of the green community on your school campus. In this exercise, you will practice using an aerial photograph of your school and heads-up digitizing (tracing features on-screen) the tree canopy and non-tree canopy features of a study area. You will then use CITYgreen's GIS capability to analyze and create models of the area.

BEGINNING YOUR PROJECT

1. Open ArcView, blank project, file, extension, check (click), CITYgreen (ok), double click on VIEW PROPERTIES, set map units to feet, double click on local, click on BROWSE, go to where the aerial photo is located, school.tif (ok), next screen (ok), file, go to cg4folder and save the project as: Your name (6Nov02jennifer.apr).

DIGITIZING THE STUDY AREA

2. From CITYgreen menu, select CREATE CITYgreen THEME.
3. Select STUDY AREA from drop down box and click OK.
4. Draw Study Area dropdown box appears reminding you to use the DRAW tool; click ok.
5. Draw the study area boundary around the perimeter of your sample study site. Click once to enter each point on the line and then Double Click to complete the polygon (shape). If you want to erase and start over, press the delete key.

6. When done click the STOP EDITING button to save your edits.

DIGITIZING THE TREES

1. Click on the zoom button and enlarge the image in the View so you can see the image more clearly.
2. From the CITYgreen menu, select CREATE CITYgreen THEME.
3. Select TREES from the dropdown box and click ok.
4. Keep tree1 and click ok.
5. Click NO to the question "Do you wish to enter attributes as you add features".
6. With the tree draw tool position the cross-hairs of the cursor over the center of an individual tree.
7. Click and hold down the left mouse button and drag to the size of the canopy, then release.
8. To erase and redraw the tree, press delete and start over.
9. **DIGITIZE 10 trees** using the zoom and pan buttons to navigate around.
10. When you are done, select the STOP EDITING button.
11. Click yes to save edits.
12. From the file menu SAVE PROJECT in your folder.

DIGITIZING THE BUILDINGS

1. Click on the ZOOM tool and enlarge the image so you can clearly see the buildings.
2. From the CITYgreen menu, select CREATE CITYGreen THEME.
3. Select Buildings from the drop down menu and click ok.
4. Keep the file name Build1 making sure that you are saving in the correct directory.
5. Use the building draw tool the same way you used the tree tool. Position the cross hairs at the corner of an individual building and trace the outside by clicking on each corner. Click once to enter each point on the line and then Double click to complete the polygon.
6. Roofs are red polygons (shapes). If you wish to erase, press the delete button and start over.
7. **DIGITIZE 6 buildings** and then stop by clicking the stop editing button (hand palm up).
8. From the file menu save your project to the correct folder.

DIGITIZING IMPERVIOUS SURFACES

Impervious surfaces are objects that do not allow rain to be absorbed into the ground like pavement, driveways, roads, etc.

1. Click on the ZOOM tool and enlarge the image so you can clearly see the driveways.
2. From the CITYgreen menu, select CREATE CITYgreen THEME.
3. Select impervious surfaces the drop down menu and click ok.
4. Keep the file name "imsurf1" making sure that you are in the correct directory.
5. Use the impervious drawing tool much the same way that you used the tree tool. Position the cross hairs at the corner of a driveway to one of your buildings you

digitized and trace the outside by clicking on each corner. Click once to enter each point on the line and then Double click to complete the polygon.

6. Impervious surfaces are gray polygon (shapes). If you wish to erase, press delete button to start over.
7. **DIGITIZE 6 driveways** and then stop by clicking the stop editing button (hand palm up).
8. From the file menu save your project to the correct folder.

DIGITIZING AIR CONDITIONERS

1. Click on the ZOOM tool and enlarge the image so you can clearly see the red houses that you digitized.
2. From the CITYgreen menu, select CREATE CITYgreen THEME.
3. Select Air conditioners from the drop down menu and click ok.
4. Keep the file name "Acd1" making sure that you are in the correct directory to save.
5. Use the air conditioner drawing tool much the same way that you used the tree tool. Position the cross hairs at a location on the outside of one of the buildings you digitized.
6. Air conditioners will be a turquoise dot (point). If you wish to erase, press delete button to start over.
7. **DIGITIZE 6 air conditioners** and then stop by clicking the stop editing button (hand palm up).
8. From the file menu save your project to the correct folder.

CREATE AND PRINT A FIELD MAP

1. Number the trees using the AUTO-INCREMENT button. First activate (raise) the tree theme on the left side of your screen.
2. Click on the AUTO-LABEL button (has the ABC on the button).
3. A label box appears: SELECT FIND BEST PLACEMENT and ALLOW OVERLAPPING LABLES and SCALE LABELS. Click OK to create the labels. ID numbers appear over each tree in the view.
4. From the CITYgreen menu select PRESENTATION MAP
5. Choose landscape.
6. Use the pointer tool by clicking and pointing where the title is and change Site 1 to YOUR name and Map Example "Brad's CITYgreen Map".
7. Save your project in your folder and print a copy to turn into your teacher.

ENTERING TREE FIELD DATA

1. Activate the tree theme and click on the TREE INFO button in the menu (has a picture of a tree on it).
2. The Enter Tree Data dialog box appears. Click on the tree number and enter the data from the menu dialog box. Choose trees and hypothesize data regarding tree height and diameter that you think is realistic.
3. Click on another tree ID number and repeat the process for all 10 trees.
4. When you are finished entering the data, click CLOSE.

ENTERING BUILDING FIELD DATA
This data is entered directly into the data table.

BUILDING DATA TO BE ENTERED

Building ID #	Air Cond.	NumStories	Roofcolor
1	Y	2	black
2	Y	1	dark grey
3	Y	2	light grey
4	Y	2	white
5	Y	1	black
6	Y	1	white

1. Activate the building theme.
2. Click OPEN THEME TABLE.
3. From the TABLE menu select START EDITING.
4. Click on the EDIT tool (I) which allows you to type in the cells.
5. Click inside a cell and enter inventory information from your field survey using ALL CAPITAL LETTERS.
6. Enter to move to the cell below and TAB over to the cell to the right.
7. To quite from the TABLE menu, select STOP EDITING.
8. At the prompt click YES to save edits.

RUNNING THE CITYgreen ENVIRONMENTAL ANALYSIS
Once you have accurately digitized all the map features and entered all the necessary field inventory data into the attribute tables, you are ready to run the CITYgreen analysis of the environmental benefits provided by your green community. The analysis quantifies the amount and value of the environmental benefits provided by the tree canopy, calculates the carbon sequestration (the amount of carbon stored up), air pollution removal, summertime residential energy savings, storm water runoff reduction and the wildlife benefits provided by your study site.

PREPARING SITE STATISTICS
1. From the CITYgreen menu select SITE STATISTICS
2. From the Scenario dropdown box click on SCENARIO 1
3. From the land use type click on Residential.
4. Place a check mark in the box next to the words AUTOMATICALLY CALCULATE STATISTICS UPON SELECTION.
5. In the study area select study1. CITYgreen automatically will calculate the statistics of your study area and displays it in a summary results box.
6. Repeat for tree1 and build1. Read the results box for each theme or set of data.
7. Select the IMAGE file for the aerial photo of your school.
8. Click on DONE when you have completed the statistics.

ANALYZE ENVIRONMENTAL BENEFITS

1. From the CITYgreen menu select ANALYZE STUDY AREA.
2. The CITYgreen analysis dialog box appears.
3. From the Scenario dropdown box select SCENARIO ONE.
4. CITYgreen automatically generates a CARBON ANALYSIS displayed in the results box.
5. Choose POLLUTION next and use an average of 10 cities. CITYgreen automatically generates the results.
6. Choose STORMWATER and for the SOIL GOUP CHOOSE C - Somewhat impervious. This represents the general soil type of North Carolina. Rainfall region is II and slope is 2% and average 24 hour Precip. Amt. (in) is 2. Then click on the RUN ANALYSIS button.

ENERGY CONSERVATION AND AVIOIDED CARBON EMISSIONS.

CITYgreen estimates the direct shading benefits that trees provide to residential buildings within a study area by calculating the dollar savings for the study site. By conserving energy, trees make a contribution to the environment by reducing the carbon emissions from energy production.

1. Remain in the ANALYZE STUDY AREA dialog box for Scenario one.
2. Click on the ENERGY button.
3. On the left hand side, click on the file folder and SELECT the AIR CONDITIONER theme that you created.
4. Place a check mark in the APPLY COOL ROOF MODULE box to estimate the cooling benefits of light roofs and one and two story buildings.
5. Place a check mark in the CALCULATE LOCATION RATINGS BOX to calculate the shade benefits of trees to one and two story buildings.
6. Select the STATE in which you live in from the drop down menu box.
7. Enter the average annual cooling cost per home in the annual cooling cost per home box and the number of homes that was used to calculate this average.
8. Select the RUN ANALYSIS button and wait a minute for the results to be calculated.
9. You will use the WILDLIFE BENEFITS and also MODEL TREE GROWTH when you complete your analysis of your school site.

PRINT ANALYSIS RESULTS

1. From the CITYgreen menu select DATA SHEET.
2. The data sheet dialog box appears. Select SCENARIO ONE from the Scenario dropdown box.
3. The study area theme, tree theme, building theme, and image theme should all automatically appear in the menu box.
4. Click CREATE DATA SHEET. The newly created DATA sheet appears in the Layout window.
5. From the file menu select PRINT and OK to print a map of your results.

APPENDIX C – PROBLEM SOLVING VERBAL AND GRAPHIC MAP

Problem Solving Graphic Map	
What is the problem? _____	
Facts about the problem	**Ideas of ways to solve the problem**
What would happen if you solved the problem each of these ways?	
Ideas	**Predictions**
Best statement of the problem _____ _____	

Problem Solving Verbal Thinking Map	Scientific Research
Why is there a problem?	Background
What is the problem?	Problem Question
What would happen if you solved the problem in this way?	Hypothesis/Procedure
What is the best solution to the problem?	Data/Results
What are the possible solutions to the problem?	Conclusion
If you did it again, what would you do differently?	

Source for skillful problem-solving: From Infusing the Teaching of Critical and Creative Thinking Into Content Instruction (p. 78), by R. Swartz and S. Parks, 1994, CA: Critical Thinking Press and Software. The National Center for Teaching Thinking

APPENDIX D – SIX WEEK SCHEDULE

Send home consent letters and give Purdue Spatial Visualization test, Learning Styles Inventory, and Spatial Experience Survey before the study begins.

Mapping Our School Site (MOSS)		CITYgreen	
Week One	*Introduce problem solving and review the parts of a science experiment. *Use the Website to discuss the overall problem questions. * Use the GIS general Powerpoint to introduce what is GIS. *Discuss places on campus where you should place your 10 m by 10 m plot. *Measure and stake out the plot and practice taking measurements using the grid. *Go outside and make general observations. *Divide students up into lab groups and decide on the lab jobs for the 5 initial plot procedures. *Review equipment, data collection procedures, and outside rules with students. *Begin collecting the data outside on the 5 initial procedures.	Week One	Introduce problem solving and review the parts of a science experiment. *Use the CITYgreen and other references to discuss the overall problem questions *Use the GIS general Powerpoint to introduce what is GIS. *Determine your school campus boundary for the CITYgreen study. *Determine a management plan - what sections will you analyze first? *Go outside and make general observations about the site. *Divide students up into lab groups. *Review equipment, data collection procedures, and outside rules with students. *Digitize the trees on the aerial photograph of your school and create a tree survey map.
Week Two	*Finish collecting the data outside on the 5 initial procedures. *Enter the data into the computer in EXCEL on the spreadsheets provided on the MOSS web site.	Week Two	*Go outside and demonstrate the data collection procedure and how to enter the data into the CITYgreen tree spreadsheet. *Begin data collection of trees on your study site.
Week Three	*Students share data from all 5 procedures to create group projects. *A jigsaw of each group sharing their results can be used to discuss initial data findings. *Students digitize and create the ground cover layer. *Students use the 5 layers to generate a list of patterns in the data and possible problem questions. *Each lab group chooses one problem question, researches and designs a procedure to answer that problem question.	Week Three	*Assign one lab group the responsibility of entering the tree data into the CITYgreen program on a lap top computer in the field. *Form groups of students to collect data on the sidewalks, air conditioners, shrubs, grass, bare ground and buildings. *Review the data collection procedures and collect the data on these layers.
Week Four	*Students return to the study site and collect data on individual procedures. *Students enter the data into EXCEL and add it to their class projects. *Students use ArcView to analyze the data and produce a map and a conclusion.	Week Four	*Enter the remaining data into the CITYgreen program. *Use CITYgreen to generate statistics and the tree growth model. *Discuss results with the students.
Week Five	*Students write one lab report per group. *Students present their study results to the class.	Week Five	*The students investigate a series of scenarios and discuss results. *Students generate a list of problem questions they analyze using the CITYgreen modeling program *Each student group presents their lab report findings to the class.
Week Six	*Students write an individual conclusion about their lab group's investigation. *Students take an objective test on the unit.	Week Six	*Students write an individual conclusion about the CITYgreen class project. *Students take an objective test on unit.

APPENDIX E - MOSS QUIZ

MOSS - Study Site Quiz

Matching

_____1) an insect has this many legs	A. species
_____2) books used to identify things	B. number of square meters in site
_____3) spiders, knats, and crickets	C. shrubs, grass, bare ground
_____4) DBH	D. used to find directions such as North
_____5) liquid inside pitfall traps	E. clay, loam, sand
_____6) size of study site	F. X and Y
_____7) abiotic and biotic	G. found in data tables
_____81) location	H. field guides
_____9) clinometer	I. examine these to ask problem questions
_____10) soil texture	J. used to mark pitfall traps
_____11) field flags	K. animals without backbones
_____12) abiotic group	L. geographic information systems
_____13) rows and columns	M. diameter breast height of trees
_____14) patterns	N. examples of what was found in pitfall traps
_____15) scientific name	O. non-living and living
_____16) measured by vegetation cover group	P. salt water solution
_____17) 100	Q. abundance and diversity
_____18) compass	R. six
_____19) GIS	S. length x width
_____20) environmental health	T. 10 meters square
_____21) area	U. instrument used to measure tree height
_____22) invertebrates	V. measured soil and air temperature

……

List 3 problem questions that you thought of as we did this project. Tell how you would test each one.

1)

_____
_____
_____
_____

2)

_____
_____
_____
_____

3)

_____
_____
_____
_____

APPENDIX F - CITYGREEN GIS QUIZ

CITYgreen Quiz

Matching

_____1) roof albedo	A. species
_____2) books used to identify things	B. school campus
_____3) energy conservation	C. trees store and sequester this gas
_____4) DBH	D. good, fair, poor, very poor
_____5) tree canopy	E. benefit provided by trees
_____6) size of study site	F. X and Y coordinates
_____7) abiotic and biotic	G. found in data tables
_____81) location	H. field guides
_____9) clinometer	I. examine these to ask problem questions
_____10) carbon	J. water cannot go through this type of material
_____11) aerial photograph	K. uses data to create models of the study
_____12) scenarios	L. geographic information systems
_____13) rows and columns	M. diameter breast height of trees
_____14) patterns	N. computer program used to plan cities
_____15) scientific name	O. non-living and living
_____16) CITYgreen	P. measure of reflectivity
_____17) inventory map	Q. abundance and diversity
_____18) tree condition	R. used to keep track of tree locations in field
_____19) GIS	S. length x width
_____20) environmental health	T. "picture" taken from above the object
_____21) area	U. instrument used to measure tree height
_____22) impervious surfaces	V. area of tree crown

……

List 3 problem questions that you thought of as we did this project. Tell how you would test each one.

1)

_____
_____
_____
_____
_____
_____
_____

2)

_____
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3)

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APPENDIX G - MOSS/CITYGREEN TEST

Unit Test for MOSS and CITYgreen

Directions: Read each question carefully and completely fill in the circle of the letter that represents the MOST correct or BEST answer to each question below. Answer ALL of the questions on the test.

1) What is GIS?
   a) a tool for analyzing information.
   b) a way of seeing maps in a visual way.
   c) a software program that you use on your computer.
   d) information that has location and is in layers.
   e) all of the above

2) How does GIS work?
   a) by tracing maps into the computer and then asking questions.
   b) you can enter the data into spreadsheets and find it later.
   c) it uses points, lines, and polygons for analysis or display.
   d) by collecting data outside and then typing it into the computer.
   e) by drawing maps on the computer that you can look at.

3) What does GIS do?
   a) it solves problems and can answer any question.
   b) it creates relationships among geographic things, objects, and measurements.
   c) it represents the earth and the earth is not much different.
   d) it helps all data become the same.

4) In GIS the data is stored as:
   a) points, lines, and polygons
   b) a series of points
   c) a series of lines
   d) a group of polygons
   e) points and lines but not polygons
   f) polygons but not points and lines

5) Why is it important to measure tree height, type, species, and size?
   a) it effects other non-living parts of the environment like light and shade.
   b) it is a part of the data table and needs to be entered into the computer.
   c) it relates to the other animals that will be able to live there.
   d) it is needed to manage the trees on the school grounds.
   e) both a and c

6) How do you know what size to make your study site?
   a) it is based upon how much time it takes to collect the data.
   b) it is whatever I or the class decide to make it.
   c) the GIS program decides the size of the study site.
   d) through research on what others have done when doing similar experiments.
   e) it depends on my problem question, data and what I want to study.

7) What is a very important component of every spreadsheet or attribute table?
   a) making sure each record or row has a number.
   b) each object in the table must have BOTH an x and y location.
   c) the items in the tables must have information about them in the table.
   d) each object in the table only needs an x OR a y location.

8) The circled name in the table below is called a _____ name and it is at the top of a _____.
   a) field, column
   b) object, row
   c) number, column
   d) row, column

NAME	STATE_NAME	STATE_FIPS	CNTY_FIPS	FIPS	POP1990	POP90_SQMI
Autauga	Alabama	01	001	01001	34222	57
Baldwin	Alabama	01	003	01003	98280	62
Barbour	Alabama	01	005	01005	25417	29
Bibb	Alabama	01	007	01007	16576	27
Blount	Alabama	01	009	01009	39248	61
Bullock	Alabama	01	011	01011	11042	18
Butler	Alabama	01	013	01013	21892	28
Calhoun	Alabama	01	015	01015	116034	190
Chambers	Alabama	01	017	01017	36876	62
Cherokee	Alabama	01	019	01019	19543	35

9) The highlighted line in the spreadsheet or attribute table below is called a _____ and it corresponds to a _____ on the map.
   a) column, number
   b) row, number
   c) row, object or feature
   d) column, location

ID	X_m	Y_m	canopy_obs	ground_obs	tree_name
1.0	30.0	30.0	Y	B	Red Oak
2.0	29.0	29.0	Y	B	Red Oak
3.0	28.0	28.0	Y	G	Loblolly Pine
4.0	27.0	27.0	N	G	Loblolly Pine
5.0	26.0	26.0	N	G	Grapevine
6.0	25.0	25.0	N	B	Black Cherry

10) When designing a spreadsheet or table, what is the most important thing to consider?
   a) think about the type of information that is going to be entered into the table.
   b) think about the other objects that are in the other tables in the project.
   c) the only you need to consider is how it can be stored in the computer.
   d) think about your hypothesis, relationships, and what questions you would like answered.

11) Modeling is very important in science. What do you do when you create a model?
   a) analyze how the parts relate to each other.
   b) use the current information to predict what might happen in the future.
   c) add additional information to what you already know.
   d) create numbers and statistics on the scientific process you are studying.

12) What does it mean to study the abiotic and biotic components of an environment?
   a) to look at how the living parts of an environment relate to each other.
   b) to study how humans relate to their environment.
   c) to look at how the non-living and living parts of it relate to each other.
   d) to study how animals and plants relate to each other.

13) In order to determine the names of the living and non-living things in the environment we used a special taxonomic system found in a(n)_____?
   a) field guide.
   b) science textbooks.
   c) encyclopedias.
   d) website.

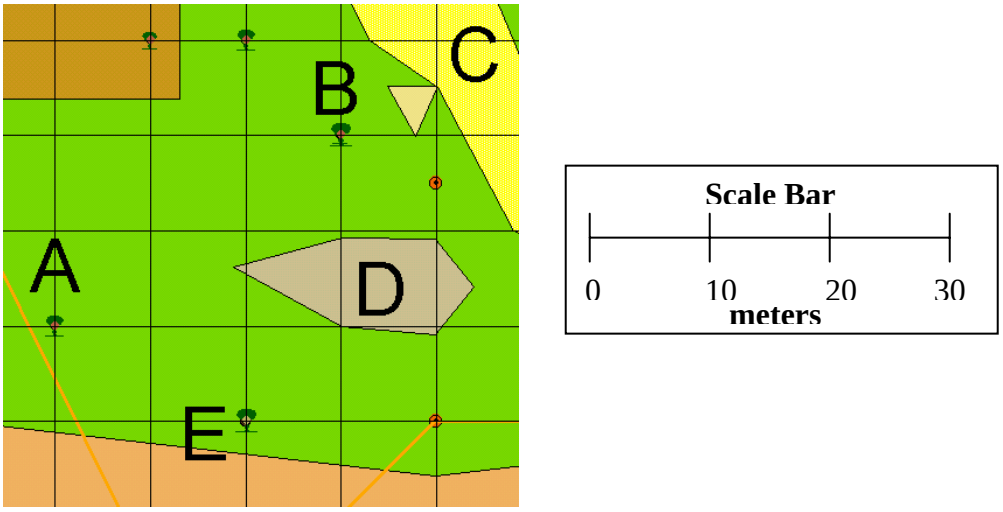
14) DBH stands for what and is representative of what characteristic?
    a) detailed board habit, leaf size.
    b) damage branch height, branch length.
    c) depth bole half, tree trunk density.
    d) diameter breast height, tree size.

15) Why is it important to understand the type and how much "green" space there is in an environment?
    a) people like to see and enjoy the trees, grass, and shrubs.
    b) it is a good indicator of the health and diversity of an environment.
    c) we need green plants to produce oxygen for us to breath.
    d) it keeps buildings and the soil cooler in the summer time.
    e) scroll through the tables and records and look for the answer.

16) Which way would be the best to use to solve a complex problem?
    a) decide on a problem question to study, look at which solutions are possible, decide which solution you are going to do.
    b) choose a problem question to study, compile information, generate a solution, draw a conclusion.
    c) define the general problem, ask problem questions, generate possible solutions, decide on best solution to the problem based on the information.
    d) look at the information and pick a problem question, generate a solution, draw a conclusion.

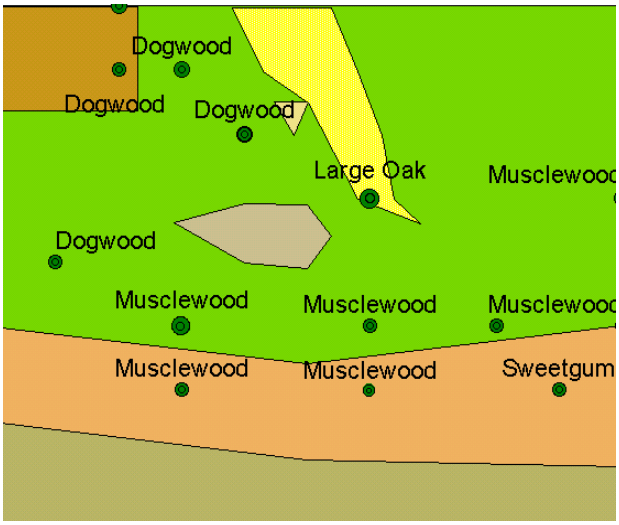
17) Using GIS, what is the best sequence to use when answering complex problem questions such as those in this project?
    a) use tools such as the "i" tool, color coding and labels.
    b) look at and change colors, zoom in and out, and look for the answer on the map.
    c) collect any needed data, add it, create queries, and ask the map questions.
    d) create a series of queries and ask the map questions..
    e) scroll through the tables and records and look for the answer.

18) Approximately how far is it from E to D?
   a) 20 meters
   b) 5 meters
   c) 50 meters
   d) 10 meters



19) What direction would a person be traveling if they went from E to D? (see map in question 18)
   a) west.
   b) south.
   c) east.
   d) north.

20) What do the polygons on this map most likely represent?



a) only trees.
b) only bare ground.
c) vegetation cover.
d) shrubs and grass.

21) How do you draw polygons on a map like those in question numbers 20 and 21?
a) through a process called digitizing.
b) by adding the data from the data table or spreadsheet.
c) by using colored pencils and a grid.
d) through a series of drawn areas on the map.

22) What do these two areas have in common?





a) large amounts of grass.
b) many large mature trees.
c) sloping hills.
d) mostly shaded areas.

23) List 3 problem questions that you thought of as we did this project. Tell how you would test each one.

1)

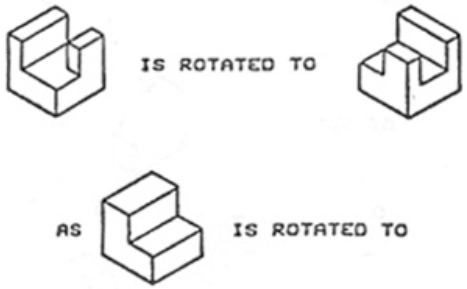
2)

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APPENDIX H - PURDUE SPATIAL VISUALIZATION TEST: ROTATION

Directions

This test consists of 30 questions designed to see how well you can visualize the rotation of three-dimensional objects. Shown below is an example of the type of question included in the second section.



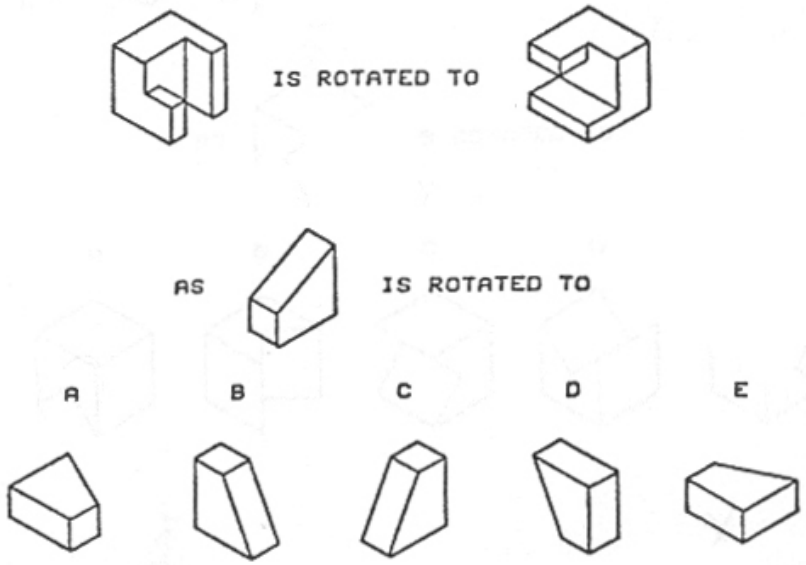
You are to:

1. study how the object in the top line of the question is rotated;
2. picture in your mind what the object shown in the middle line of the question looks like when rotated in exactly the same manner;
3. select from among the five drawings (A, B, C, D, or E) given in the bottom line of the question the one that looks like the object rotated in the correct position.

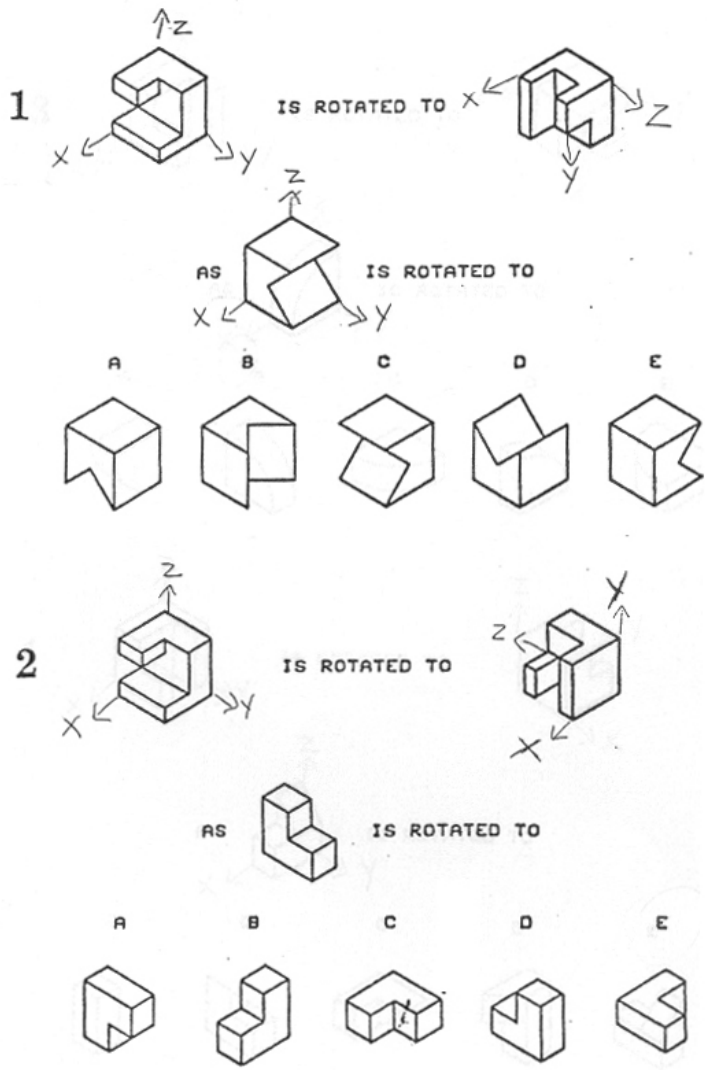
What is the correct answer to the example shown above?

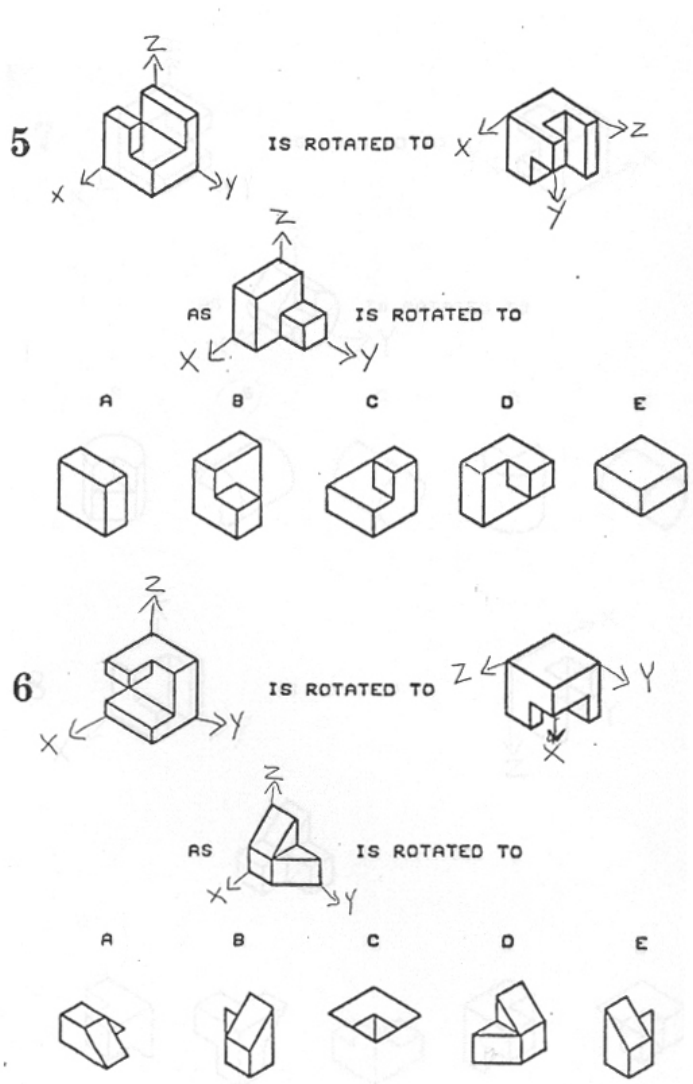
Answers A, B, C, and E are wrong. Only drawing D looks like the object rotated according to the given rotation. Remember that each question has only one correct answer.

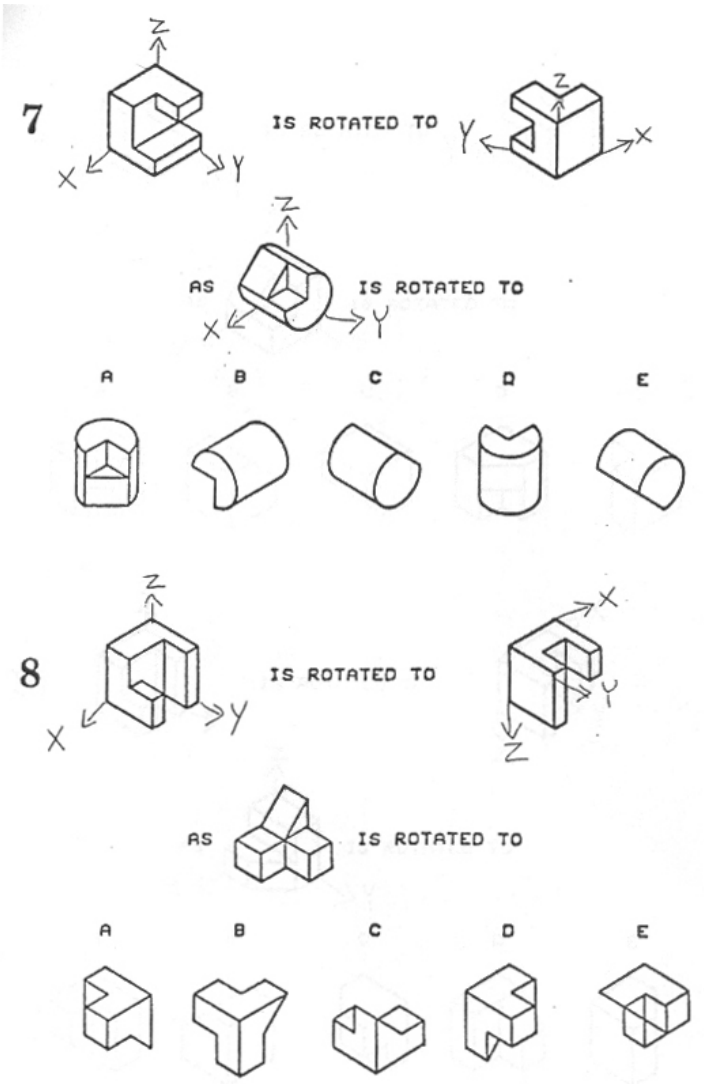
Now look at the next example shown below and try to select the drawing that looks like the object in the correct position when the given rotation is applied.

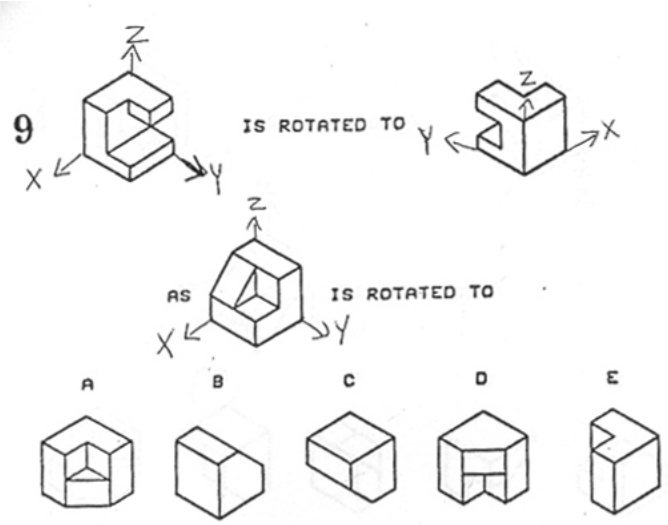


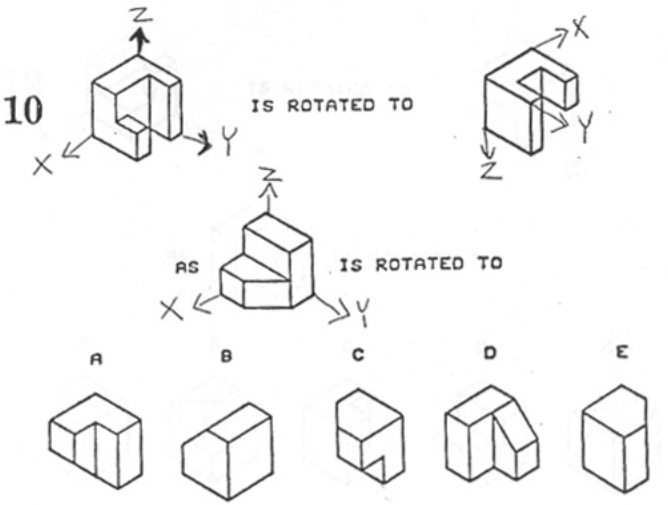
Notice that the given rotation in this example is more complex. The correct answer for this example is B.

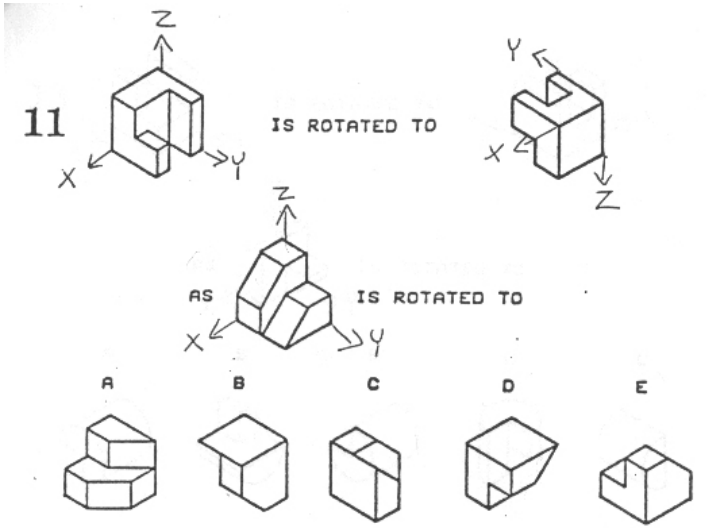

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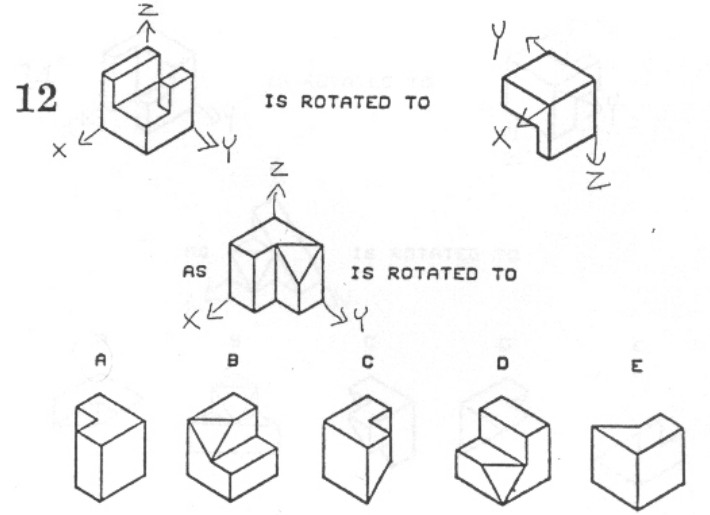

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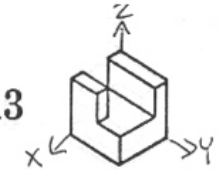

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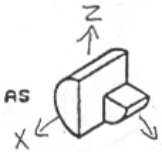
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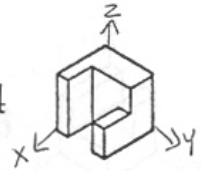


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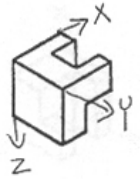
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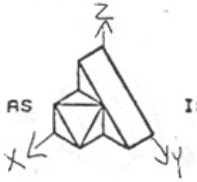
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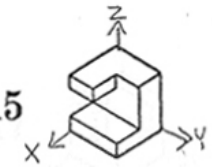


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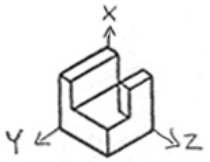
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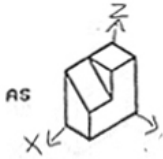
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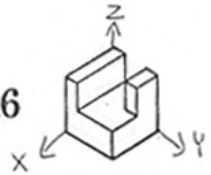


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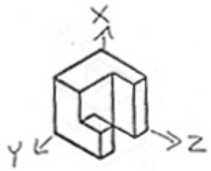
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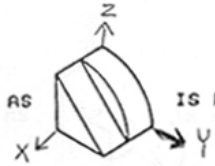
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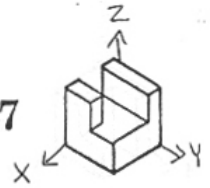


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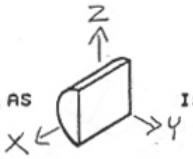
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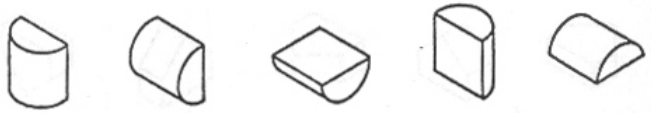


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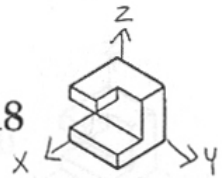


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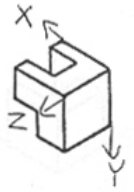
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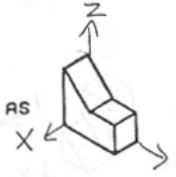
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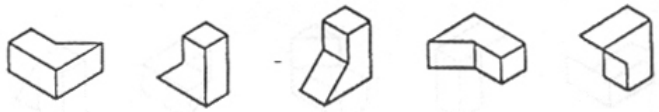


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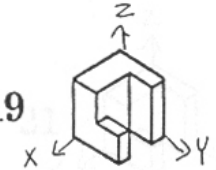


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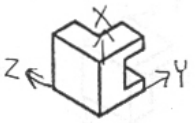
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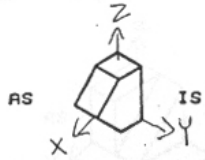
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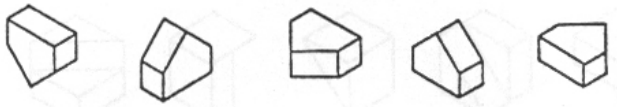


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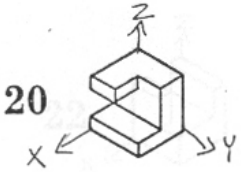


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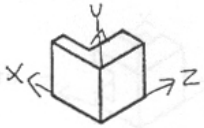
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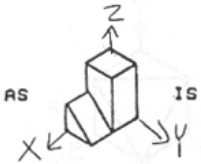
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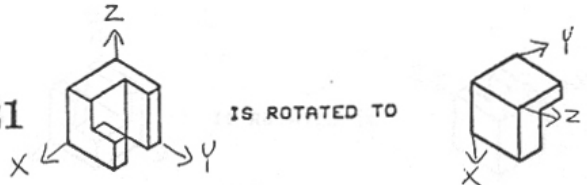


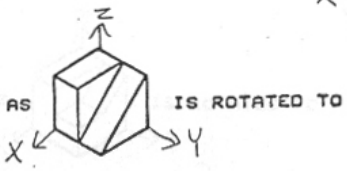
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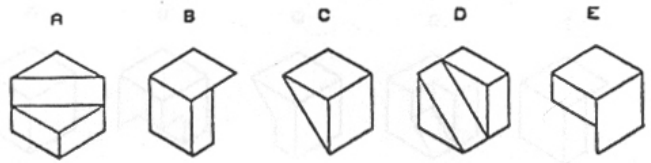
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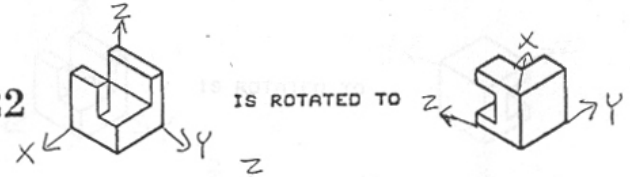
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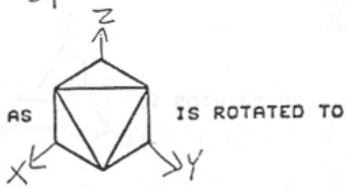

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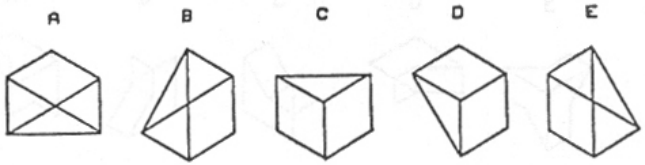

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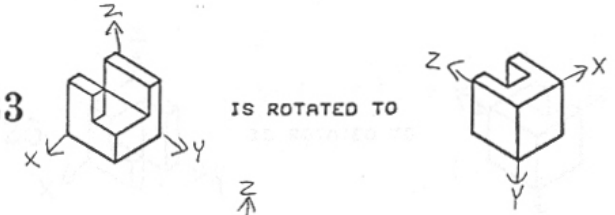
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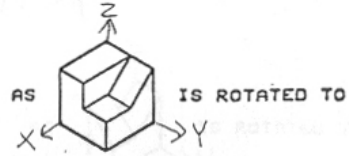

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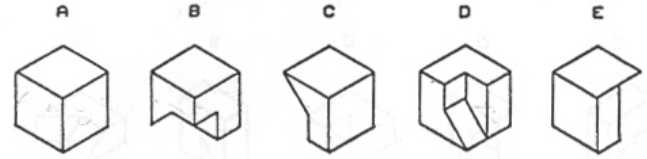

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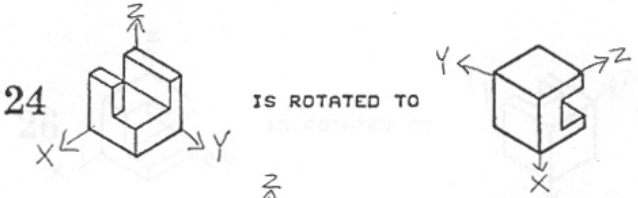
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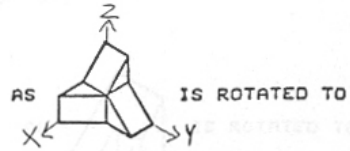

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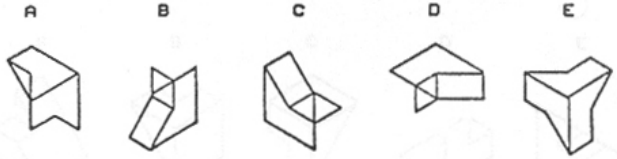

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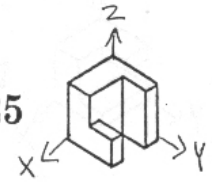
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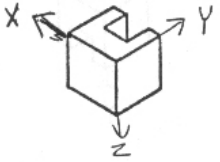

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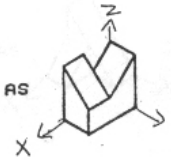
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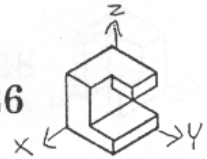


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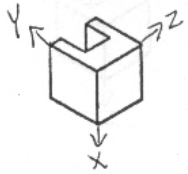
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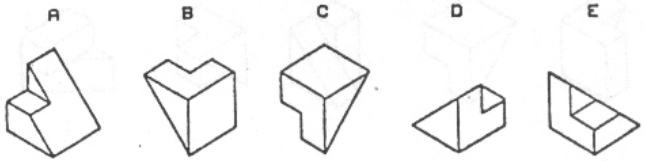


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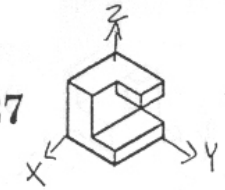


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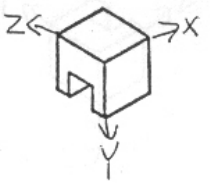
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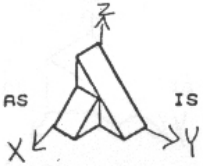
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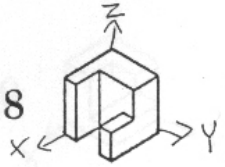


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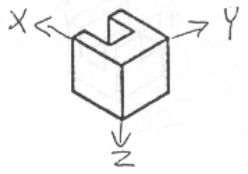
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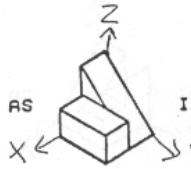
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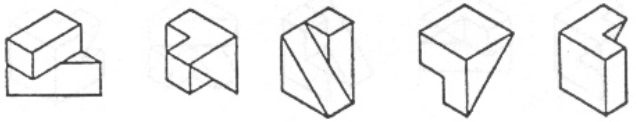


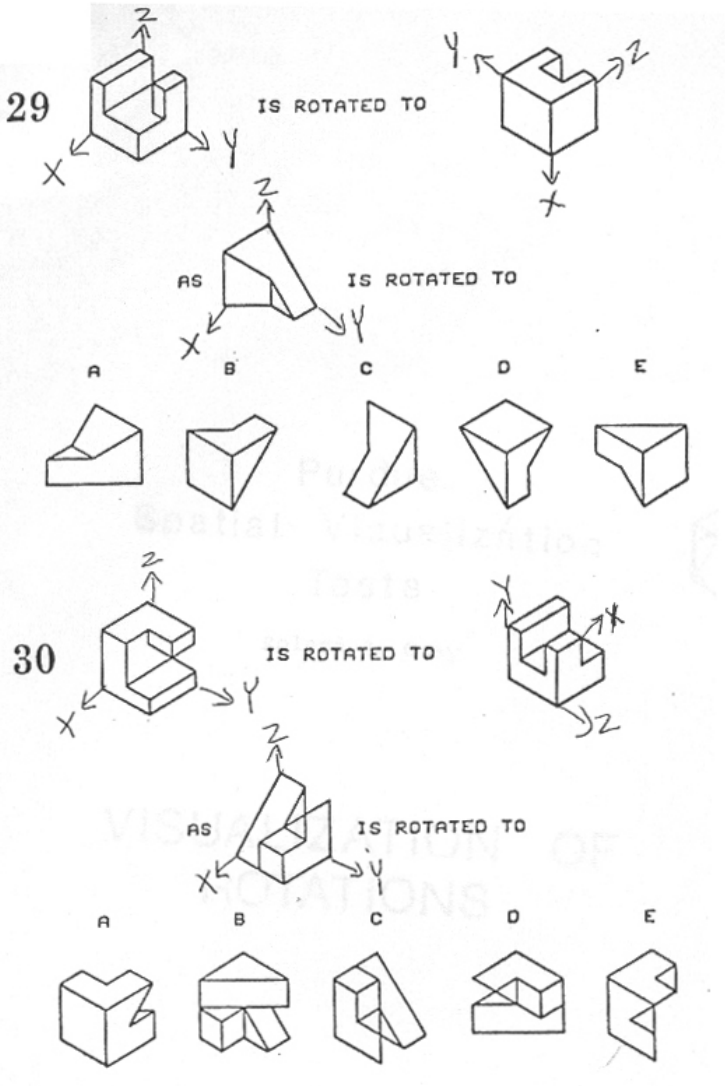
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APPENDIX I - SPATIAL EXPERIENCE SURVEY (SES) FOR ADULTS

Project Survey

Please complete all the questions on this survey. DO NOT skip any questions and answer all of them to the best of your ability.

Contact Information

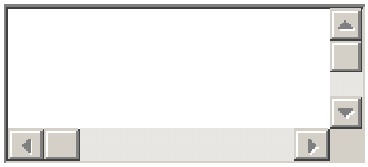
Your Name :

School Name:

1. How much GIS experience do you have?

- Beginner
- Intermediate
- Advanced
- Expert

Please explain in the box below why you are at this level? Courses? Workshops? Use with your students?



What grade and subject did you teach last school year and what grade and subject will by be teaching this coming school year?



2. What is your gender?

- Female
- Male

3. What is your age?

- ☐ 16-19
- ☐ 20-25
- ☐ 26-30
- ☐ 31-35
- ☐ 36-40
- ☐ 41-50
- ☉ 50+

4. What is your highest educational level?

- ☐ High school graduate
- ☐ College freshman
- ☐ College sophomore
- ☐ College junior
- ☐ College senior
- ☐ Undergraduate degree
- ☐ Master's candidate
- ☐ Master's degree
- ☐ PhD candidate
- ☐ PhD degree

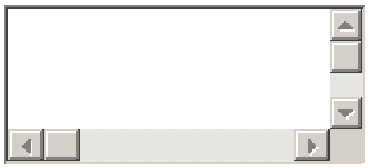
5. Are you right-handed or left-handed?

- ☐ Left-handed, and no other immediate family member (i.e. parents, siblings, or grandparents) is left handed
- ☐ Right-handed
- ☐ Ambidextrous (i.e.feel equally comfortable using right or left hand)
- ☐ Left-handed, and at least one other immediate family member is left-handed

6. Have you ever taken a geometry class? (ever, including high school) If yes, did the class include the study of 3-dimensional objects such as cubes and prisms?

- ☐ No, I have not taken geometry
- ☐ Yes, I have taken geometry but it **did not** include the study of 3-D objects
- ☐ Yes, I have taken geometry it **did** include the study of 3-D objects

7. What is your major?

- ☐ Forestry
- ☐ Natural Resources
- ☐ Park, Recreation and Tourism
- ☐ Marine, Earth and Atmospheric Sciences
- ☐ Education and Psychology
- ☐ Agriculture and Life Sciences
- ☐ Computer Science
- ☐ Engineering
- ☐ Management/Economics
- ☐ Marine, Earth and Atmospheric Sciences
- ☐ Mathematics/Statistics
- ☐ Chemistry/Physics
- ☐ other(s): Please list 

8. Have you ever taken a course(s), other than geometry, in which you drew 3-D objects (for example, mechanical drawing, drafting, technical design, CAD drawing, art, etc……)

- ☐ No, I have never taken such a class
- ☐ Yes, I have spent 1/2 to 1 year in such a course(s)
- ☐ Yes, I have spent 1 1/2 to 2 years in such courses
- ☐ Yes, I have spent 2 1/2 to 3 years in such courses
- ☐ Yes, I have spent 3 1/2 to 4 years in such courses
- ☐ Yes, I have spent 4 1/2 to 6 years in such courses
- ☐ Yes, I have spent over 6 years in such courses

9. Which of the following toys did you play with as a child or a teenager? (Check all that apply)

- ☐ Legos
- ☐ Erector sets, Capsula or Kinnex
- ☐ Blocks
- ☐ Tinker Toys
- ☐ Lincoln Logs

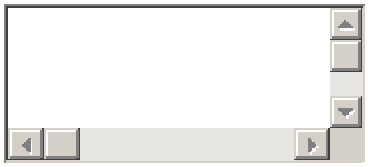
10. Have you ever taken a course(s) in the building of solid objects or structures (for example, wood shop, metal shop, machine shop...)?

- ☐ No, I have never taken such a class
- ☐ Yes, I have spent 1/2 to 1 year in such a course(s)
- ☐ Yes, I have spent 1 1/2 to 2 years in such courses
- ☐ Yes, I have spent 2 1/2 to 3 years in such courses
- ☐ Yes, I have spent 3 1/2 to 4 years in such courses
- ☐ Yes, I have spent 4 1/2 to 6 years in such courses
- ☐ Yes, I have spent over 6 years in such courses

11. Did you play video/computer games as a child or teenager (for example, Tetris, Doom, Quake, etc...)?

- ☐ Never
- ☐ Every few months
- ☐ Monthly
- ☐ Weekly
- ☐ Daily

12. In which of the following sports were you "actively involved" during your high school years or grades 9-12? ("Actively Involved" means you either participate in the sport as a competitor for your high school or it is a sport you played frequently outside of school. Please mark all that apply.)

- ☐ I am not "actively involved" in a sport
- ☐ football
- ☐ basketball
- ☐ hockey/broomball/field hockey
- ☐ baseball/softball
- ☐ golf
- ☐ soccer/rugby
- ☐ tennis ping pong
- ☐ volleyball/walleyball
- ☐ racquetball/squash
- ☐ ultimate frisbee
- ☐ other(s): Please list 

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APPENDIX J - SPATIAL EXPERIENCE SURVEY (SES) FOR STUDENTS

Project Survey

http://www2.ncsu.edu/unity/lockers/project/gc-ted/survey.html

Please complete all the questions on this survey. DO NOT skip any questions and answer all of them to the best of your ability.

Contact Information

Your Name :

School Name:

1. How much GIS experience do you have?

- ☐ Never heard of it
- ☐ Know what GIS means
- ☐ Use GIS on a computer
- ☐ Understand how to use a GIS program

2. Are you:

- ☐ Female
- ☐ Male

3. What is your age?

- ☐ 6-7
- ☐ 8-9
- ☐ 9-10
- ☐ 11-12
- ☐ 12-13
- ☐ 13-14
- ☐ 14-15

4. What is your grade?

- ☐ 6th
- ☐ 7th
- ☐ 8th
- ☐ 9th

5. Are you right-handed or left-handed?

- ☐ Left-handed, and no other immediate family member (i.e. parents, siblings, or grandparents) is left handed
- ☐ Right-handed
- ☐ Ambidextrous (i.e.feel equally comfortable using right or left hand)
- ☐ Left-handed, and at least one other immediate family member is left-handed

6. Have you ever taken a geometry class? If yes, did the class include the study of 3-dimensional objects such as cubes and prisms?

- ☐ No, I have not taken geometry
- ☐ Yes, I have taken geometry but it **did not** include the study of 3-D objects
- ☐ Yes, I have taken geometry it **did** include the study of 3-D objects

7. Have you ever taken a class(es), other than geometry, in which you drew 3-D objects (for example, mechanical drawing, drafting, technical design, CAD drawing, art etc...)

- ☐ No, I have never taken such a class
- ☐ Yes, I have spent 1/2 to 1 year in such a class(es)
- ☐ Yes, I have spent 1 1/2 to 2 years in such classes
- ☐ Yes, I have spent 2 1/2 to 3 years in such classes

8. Which of the following toys did you play with as a child or a teenager? (Check all that apply)

- ☐ Legos
- ☐ Erector sets, Capsula or Kinnex
- ☐ Blocks
- ☐ Tinker Toys
- ☐ Lincoln Logs

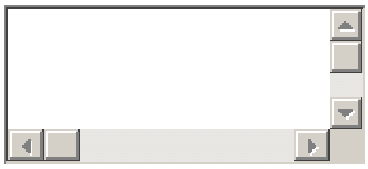
9. Have you ever taken a class(es) where you built a solid object or structure (for example, wood shop, metal shop, machine shop...)?

- ☐ No, I have never taken such a class
- ☐ Yes, I have spent 1/2 to 1 year in such a class(es)
- ☐ Yes, I have spent 1 1/2 to 2 years in such classes
- ☐ Yes, I have spent 2 1/2 to 3 years in such classes

10. Did you play video/computer games as a child or teenager (for example, Tetris, Doom, Quake, etc...)?

- ☐ Never
- ☐ Every few months
- ☐ Monthly
- ☐ Weekly
- ☐ Daily

11. Which of the following sports were you "actively involved"? ("Actively Involved" means you either participate in the sport as a competitor for your school or it is a sport you played frequently outside of school. Please mark all that apply.)

- ☐ I am not "actively involved" in a sport
- ☐ football
- ☐ basketball
- ☐ hockey/broomball/field hockey
- ☐ baseball/softball
- ☐ golf
- ☐ soccer/rugby
- ☐ tennis ping pong
- ☐ volleyball/walleyball
- ☐ racquetball/squash
- ☐ track and field
- ☐ ultimate frisbee
- ☐ other(s): Please list 

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APPENDIX K - LEARNING STYLES INVENTORY (LSI)

http://www2.ncsu.edu/unity/lockers/project/gc-ted/style.html

Assessment of Your Best Learning Style
The three modes are: Auditory-Visual-Kinesthetic

Only place a check mark in each box, where you agree with each of the statements below.
If you do not agree, just leave the box empty. Go through all 40 questions.

Contact Information

Your Name :

School Name:

- ☐ 1. You find it easier to remember items you talked about in class much better than things you were asked to read from the course book.
- ☐ 2. You like to tell jokes or riddles better than seeing cartoons or doing crossword puzzles.
- ☐ 3. You like to spell out loud, and find it easier than when you have to write words down.
- ☐ 4. You understand better when you read out aloud.
- ☐ 5. As you work you often hum or whistle to yourself.
- ☐ 6. You would rather perform (or listen to) music than do (or view) art, and you would rather listen to a tape than look at a filmstrip.
- ☐ 7. Some people say that you have terrible handwriting. It's like a scrawl.
- ☐ 8. You do NOT like to copy notes and materials from the blackboard or bulletin board.
- ☐ 9. You have to struggle to keep your notes and records neat.
- ☐ 10.Sometimes you use your fingers to point at words when you read.
- ☐ 11.You hate to read from the computer, especially when the backgrounds are busy.
- ☐ 12.Sometimes when you read you mix up words that look similar (bale-ball, pill-pull, bale-hale).
- ☐ 13.Sometimes you leave out words when you write, or sometimes you get words or letters backwards.
- ☐ 14.Sometimes you make math mistakes because you don't notice the sign or because you read the numbers or directions wrong.
- ☐ 15.You do not like to do map activities. They are just not your thing.
- ☐ 16.Sometimes your eyes just bother you, but your eye test was normal, or, you have glasses which your eye doctor says are right for you.
- ☐ 17.You find that the matching test questions are a problem to sort out (over and above not knowing some of the answers).
- ☐ 18.You feel like you are the last one to notice something new--e.g. that the classroom was painted or there is a new display board in school.
- ☐ 19.You don't like silent filmstrips, pantomimes, or charades.
- ☐ 20.You do like games with lots of action or noises better than checkers or most other board games.
- ☐ 21.You like art work better than music.

☐ 22.You like it better when someone shows you what to do rather than just telling you.

☐ 23.You would rather demonstrate how to do something than make a speech.

☐ 24.Your family says that you say "Huh?" too much.

☐ 25.You usually answer questions with yes or no rather than with complete sentences

☐ 26.You are always drawing little pictures on the edges of your papers, or doodling on scratch paper.

☐ 27.You would rather receive directions in a demonstration format than in spoken form.

☐ 28.Spoken words that sound similar (bell-bill, pin-pen, Mary-marry) give you trouble. Sometimes you can't tell them apart.

☐ 29.Sometimes it seems like you always have to ask somebody to repeat what he or she just said.

☐ 30.Sometimes you find yourself tuned out (day-dreaming) staring out the window, especially when you were trying to pay attention to something.

☐ 31.You have trouble remembering things unless you write them down.

☐ 32.You like board games such as checkers better than listening games.

☐ 33.Sometimes you make mistakes when speaking (like saying "He got **expended** from schoo." instead of, "He got **expelled** from school.

☐ 34.When you watch TV or listen to the radio, someone is always asking you to turn it down.

☐ 35.You have been in speech therapy some time previously (or currently).

☐ 36.You have to go over most of the alphabet in order to remember whether, e.g.. M comes before R.

☐ 37.Often you forget to give verbally received messages (such as telephone messages) to people unless you write them down.

☐ 38.You can do a lot of things that are hard to explain with words (like fixing machines or doing knitting or sewing).

☐ 39.Sometimes you have trouble understanding a person who is talking to you when you are unable to watch the person's face and the person is speaking.

☐ 40.Often you know what you want to say, but you just can't think of the words. Sometimes you are accused of talking with your hands or calling something a whatchamacallit or a thingamajig.

Your survey responses will be recorded as you choose the Submit button.
You will then need to use the Return button at the bottom of the next page, which will allow you to interpret your results.

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[This has been adapted from *Puzzled About Educating Special Needs Students*, by Lloyd Tindall - the Wisconsin Center on Education and Work (1980)]

APPENDIX L - STUDENT INTERVIEW GUIDE

STUDENT INTERVIEW QUESTIONS

INTRODUCTION

During the next hour or so, I am going to ask you some general questions related to the MOSS or CITYgreen projects that you have been doing in your class as well as some specific questions related to what you have learned. Please answer the questions as honestly and thoughtfully as possible. Your responses will be kept confidential. Unless you have an objection, the interview will be audio taped for the purpose of recording an accurate account of your responses. The audiotape will be secured in my office and destroyed after the transcription and analysis. Do you have any questions or concerns before we begin?

1. Tell me a little about yourself and your science background? How about computers?

2. I am interested in what you think about the MOSS/CITYgreen GIS units you have been working on in class. What would you tell a friend about them if they asked you what it was all about?

Probes:

What did you like best about the project and why?

What did you like least about the project and why?

3. How does the MOSS/CITYgreen project compare to what you do in science class?

4. During the MOSS unit you spent a lot of time measuring 5 procedures. Can you tell me the names of the 5 procedures and describe what each one was measuring?

Or

During the CITYgreen unit you spent a lot of time measuring certain parts of you school campus. Can you tell me the names of what was measured and describe what each one was measuring?

5. Would you please explain a pattern that you noticed from the project? How did you know that the pattern was there?

6. On the unit test you gave _____ as an example of a pattern. Can you think of other examples?

7. Do you think that learning GIS is important? Why?

8. What other ways do you think GIS could be used in your studies?

9. Do you think that your ability to solve scientific problems has changed as a result of this unit? If so how has it changed and what do you think was most helpful?

Now I would like for you to take a look at your unit test. I have selected six items and would like to ask you some questions about your responses.

Choose 3 science content responses and ask the student to further explain their answer.

Choose 3 GIS content responses and ask the student to further explain their answer.

APPENDIX M - TEACHER INTERVIEW GUIDE

TEACHER INTERVIEW QUESTIONS

INTRODUCTION

During the next hour or so, I am going to ask you some general questions related to the MOSS and CITYgreen projects that you have been doing with your students as well as some specific questions related to science and GIS content. Please answer the questions as honestly and thoughtfully as possible. Your responses will be kept confidential. Unless you have an objection, the interview will be audio taped for the purpose of recording an accurate account of your responses. The audiotape will be secured in my office and destroyed after the transcription and analysis. Do you have any questions or concerns before we begin?

1. How confident are you in teaching and using GIS in your classroom?

2. What do you feel your students have learned or how have they benefited from the MOSS unit?

3. What do you feel your students have learned or how have they benefited from the CITYgreen unit?

4. How do the two units compare and what do you like or think could be changed about them?

5. What limitations or barriers have you encountered when using GIS in your school?

6. What future plans if any do you have for using GIS in your school?

7. Briefly outline how you use ADD EVENT THEME in the study site project.

8. What new science concepts if any did you learn from teaching the MOSS or CITYgreen unit?

9. What 3 new relationships/information did you learn as a result of these GIS applications overall?
   Please explain what you learned and how you learned it.

APPENDIX N - LAB CONCLUSION PROMPT

Name_____

Period_____

Write a conclusion to your lab group's MOSS OR CITYgreen experiment in paragraph form below. Your conclusion should be AT LEAST one paragraph in length and communicate the meaning of your results. Please write as neatly as possible.

Some questions you might want to consider are:

- What did you find out?
- How does it relate to your hypothesis?
- What patterns, meanings, or concepts did you identify?
- What data helped you to verify what you found?
- What would you do next? I
- If you did the experiment again what would you do differently next time?

APPENDIX O - LAB REPORT GUIDELINES AND LAB REPORT AND GRADING RUBRICS

Study Site (MOSS) Lab Report Guidelines

Title	Uses capital letters correctly; reflects the main idea of the experiment; brief and to the point.
Problem Question	Clearly stated; realistic problem which can be answered by the data in the project; not too narrow or too broad; correct punctuation and spelling; neat and in the correct format which is easy to follow and read.
Hypothesis	Educated guess; clearly stated and precise, neat with correct spelling and punctuation, realistic and well thought through
Background Information	At least one or two paragraphs giving basic information about the factors being studied; research may be done on the Internet of from other sources; this should be factual information related to the problem question.
Materials	List of items you used to collect the data; number, types, and amounts given for every item listed, in list form NOT sentences, nothing left out, correct spelling and neat.
Procedure(s)	Step by step list of instructions for completing this project. Tips for collecting the data easily if these were discovered. Detailed step by step list of instructions including what you did on the computer with the GIS program to answer your problem question. Every detail should be included so that someone else could do your project without much problem. Neat and correct grammar and spelling used. Each step is numbered and in a logical and correct order.
Results and Final Map	Suitable amount of data collected in order to answer the problem question. Clearly labeled charts or graphs and final map that answers to your problem question.
Conclusion(s)	Creative and inventive with two or more paragraphs explaining the following questions: What was the problem question? Why is it a problem? What was the best solution to the problem question? Did you prove or disprove your hypothesis? Any surprises? Why? Carefully explain all of your findings and results. If you did this project again would you do it differently? How? Why? How could you use this project to communicate information to others about the CITYgreen and GIS? What did you find that might be useful when considering how to utilize the area on your school grounds for various purposes? What is the value of this project? As a result of your project what suggestions do you have regarding your school grounds? What important things can be learned by using this type of problem solving?

Your project should include a group lab report with each part above included, a disk with the project copied on it, a drawn and colored map, a presentation of no more than 7 minutes in which all lab group member participate. Presentations are due on December 13th. Be prepared.

CITYgreen Lab Report Guidelines

Title	Uses capital letters correctly; reflects the main idea of the experiment; brief and to the point.
Problem Question	Clearly stated; realistic problem which can be answered by the data in the project; not too narrow or too broad; correct punctuation and spelling; neat and in the correct format which is easy to follow and read.
Hypothesis	Educated guess; clearly stated and precise, neat with correct spelling and punctuation, realistic and well thought through
Background Information	At least one or two paragraphs giving basic information about the factors being studied; research may be done on the Internet of from other sources; this should be factual information related to the problem question.
Materials	List of items you used to collect the data; number, types, and amounts given for every item listed, in list form NOT sentences, nothing left out, correct spelling and neat.
Procedure(s)	Detailed step by step list of instructions including what you did on the computer with the GIS program to answer your problem question. Every detail should be included so that someone else could do your project without much problem. Neat and correct grammar and spelling used. Each step is numbered and in a logical and correct order.
Results and Final Map	Clearly labeled graphs and final map that answers to your problem question.
Conclusion(s)	Creative and inventive with two or more paragraphs explaining the following questions: What was the problem question? Why is it a problem? What was the best solution to the problem question? Did you prove or disprove your hypothesis? Any surprises? Why? Carefully explain all of your findings and results. If you did this project again would you do it differently? How? Why? How could you use this project to communicate information to others about the CITYgreen and GIS? What did you find that might be useful when considering how to utilize the area on your school grounds for various purposes? As a result of your project what suggestions do you have regarding your school grounds? What important things can be learned by using this type of problem solving?

Your lab report and project with each part above included should be turned in with a final map (one per group). You will present your project to the class. Lab reports and presentations are due in three weeks, the second week in May.

Lab Report and Conclusion Grading Rubric

Research Process	**1-Beginning**	**2-Emerging**	**3-Developing**	**4-Improving**	**5-Mastering**
1. **Results of the Study:** What information did I collect from the experiment?	The information is incompletely displayed. There is discrepancy between the procedure and the information collected. There is an inadequate use of unit measure. Data collected does not represent class wide findings.		The information collected is adequately displayed. The information collected adequately reflects the stated procedure. The information/data collected is adequate in answering the research question. There is an adequate use of units of measure.		The information collected is highly detailed and accurate. The results are clearly displayed. The information collected indicates the student followed their procedure well. The information/data collected is comprehensive in answering the research question. There is an adequate use of units of measure.
2. **Data Analysis** (w/5 components) How did I make sense of the data I collected?	The organization of data and analysis of data is unclear. The researcher struggles to find meaning in the information displayed. The organization of the data is inadequate to support the conclusion.		The organization of data and analysis of data is adequate. The organization of the data is just adequate to support the conclusion.		The organization of the data is very clear and descriptive. The organization of the data provides clear and convincing evidence for the conclusion.
Where are things?	No hand drawn map or layout included.	Incorrect or incomplete attempt to map group data.	Accurate map or layout indicating data collected and locations for the group.		Accurate hand drawn map or layout indicating sampling locations for the group compared to class data. Data are classed correctly.

Procedure described and related to the problem question?	No additional procedure included.	Incomplete or incorrect procedure and not related to problem question.	Complete additional procedure but incorrect or incomplete explanation of procedure. Does relates to problem question.	Correct and complete additional procedure that relates to problem question	Detailed and complete description of additional procedure that clearly and directly relates to the problem question.
Where and why patterns are occurring?	No description or map that describes where and why patterns are occurring.	Incomplete or incorrect description or map describing where and why patterns are occurring	Partially correct and complete description or map describing where patterns are occurring	Correct and complete description or map describing where patterns are occurring	Complete and correct description or map of pattern showing where and why patterns are present. Both are complete and correct.
Use of logical queries to solve problem? (tools, color coding, labels)	No evidence of use of logical queries to solve problem. Data layers shown on map are the same.	Incomplete or incorrect use of logical queries to solve problem. Some layers are different but not related to solving the problem.	At least one logical query has been used to solve the problem and at least one additional necessary layer is present to solve the problem. No color-coding is present.	Use of color coding. Two or more logical queries have been performed to solve the problem question in a logical order. Some needed layers are missing to solve the problem question.	All important layers are used and a logical series of queries have been performed in order to answer the problem question. Colors are used appropriately.
5. Use of spatial queries such as buffers, proximities, and inside/outside elements?	No evidence of spatial queries to solve the problem. Data layers shown on the map are the same.	Incomplete or incorrect use of logical queries to solve the problem. Some layers are different but not related to solving the problem.	At least one additional necessary layer is present to solve the problem question		One or more spatial queries have been performed such as proximity or buffer to solve the problem question and all needed additional layers to illustrate problem solution are present.
3. Conclusion What did I find out?	The conclusion does not communicate the meaning of the results. The conclusion fails to properly interpret information or make inferences or deductions.		The conclusion adequately communicates the meaning of the results. The conclusion adequately compares or interprets information and makes some inferences or deductions.		The conclusion communicates the meaning of the results with a high degree of clarity and focus. The conclusion makes sophisticated comparisons, interpretations, inferences or deductions from the research information.

Conclusion (cont.)	The conclusion fails to identify any shortcomings of the research procedure. The conclusion fails to relate back to the hypothesis.		The conclusion fails to identify some shortcomings of the research procedure. The conclusion relates back to the hypothesis.		The conclusion identifies patterns, concepts, meanings or structures in the data or information.
Conclusion: **Further Research**: What do I do next? What questions should guide my future research in this area of study? What do I expect to find from these future questions? (future hypothesis)	Does not make a connection to the next steps in new research or in redesigning the existing procedure. The observations or descriptions related to the research question are very limited. Research questions are not answerable by a new experiment or analysis of existing data. The prediction (hypothesis) is absent or not based on assumptions.		Makes suggestions for new research ideas, which have some flaws. Makes some suggestions for improvement of existing experimental design, which is incomplete or flawed. Adequate observations or descriptions are used in determining and communicating the research question. The research question is described but some detail is missing. The research question is answerable by experiment lacks clarity. The prediction (hypothesis) lacks some assumptions or conditions.		Makes sophisticated leaps in thinking related to new research questions. Makes suggestions related to the improvement of the existing experimental design. Exemplary observations and descriptions are used in determining and communicating the research question. The research question is described clearly, completely, fully and in great detail. The research question is answerable by experiment. The prediction (hypothesis) is based on assumptions with conditions.

Adopted from KanCRN (www.kangis.org) Secondary Experimental Research-Assessment Rubric for scoring student research

APPENDIX P - STUDENT'S MOSS AND CITYGREEN EXPERIMENT RESULTS

LEESVILLE MIDDLE SCHOOL MOSS LAB GROUPS

PROBLEM QUESTION	CONCLUSION
Is the temperature cooler near the trees or away from the trees?	The temperature near the tree was cooler than one meter away. We think it is because away from the tree gets more sunlight than close to the tree.
Is the temperature greater in the tree branches or near the tree's stump?	The temperature is greater in the trees branches because heat rises.
What soil pH value supports the most vegetation?	There were more plants in the vegetation zone with a pH of around 6.0.
Where are the animals most likely to be in the study site?	More animals were found in the wooded areas of the study site.
Does a larger tree make the air and soil around the tree warmer than the affect of a smaller tree on the air and soil around that tree?	The smaller trees were warmer. The largest trees were second and the medium trees coldest. Trees affect the soil and air temperature. The type of tree and the surrounding trees make a difference.
Does leaf litter insulate the soil it is covering?	Leaf litter does insulate the ground by a matter of 0.5 - 2.0^{o}C depending on the time of day and the duration of the sun hitting the ground.
Would there be more animals by the leaves and trees than there would be by the clay?	There were more animals in the leaves than on the clay.
How is the pH of the soil related to vegetation?	The pH of the soil is related to the vegetation cover. The soil in the grass had a lower pH than the bare ground.
What is the average height of the trees in the study site and how many trees are there?	There were 65 trees in the study site and 10.6 m high for the average tree.
What is the average height of the trees in the other study site?	The average height of the trees in the other study site was 7.826m.
How much does the temperature differ in the air as compared to the ground?	The temperature for the ground was less than the air because the soil could not heat up as fast as the air.
What percentage of the soil in the study area is clay?	The average percentage of clay in the study area was 69%.
How many blades of grass were there in each quadrate of the study site?	There were approximately 3,748,148.00 blades of grass in the study site. There was more grass near the woods than in quadrate 2.
Does the temperature actually affect the number of insects that can be found or just their location?	The insects seemed to be more frequently caught in the sixth trap next to some decaying logs in the woods.
Which of the four quadrates have the highest and lowest air temperature and what are the different factors that affect the temperature?	Quadrates three and four had a higher temperature. Ground cover in quadrates one and two of the trees related to the air temperature.
Which substances are insects attracted to more - caramel, chocolate, nail polish remover, Mountain Dew?	The caramel trap had the most insects because it is sweeter and softer than the chocolate.
Which ground cover contains the most insects?	The pine needle by far had the most insects followed by the grass.

PROBLEM QUESTION	CONCLUSION
Which animals occur in each quadrate and how does the ground cover affect them?	There were ants, leaves, grass, and clay in most of the pitfall traps.
Does the location of the trees affect the number of animals found around there?	There were more animals closer to the tree, one pitfall trap away from the tree and in the grass.
What is the relationship between the ground vegetation and the soil temperature?	The soil temperature underground was the same. The soil temperature at the surface was warmer in the grass and in the clay (bare ground).
Are there more ants in the woods, grass, clay, or leaf litter?	The trees with leaf litter had the most ants.
What are the different types of textures in the four corners of the study site and which corner has the highest pH?	The northern part of the study area had a more acidic pH and than the clay area.
Are trees that are bigger in circumference taller?	Some of the taller trees had a bigger circumference than the trees that were smaller but some trees were small and had a larger circumference. Pine trees were tall but had a small circumference and Juniper trees weren't tall but had a larger circumference.
How does the soil temperature vary as the depth increases into the ground from 0cm, 20cm, 40cm, 60cm, 80cm, and 100cm?	As you go down deeper in the soil it does get colder.

CARRINGTON MIDDLE SCHOOL MOSS LAB GROUPS

PROBLEM QUESTION	CONCLUSION
Are there more insects near the bare ground or near the pond?	There were more insects in the bare ground than near the pond.
How does the chemicals in the pond water affect the microorganisms in the pond?	There were more water fleas in the areas of with higher chlorine concentration.
Where are there more insects found, in the shrubs or the bare ground?	More insects were found near the shrubs than in the bare ground.
How do the components in the water affect the aquatic life?	There were more animals found where nitrate levels were lower.
What effect does ground cover have on the soil nematode population?	There were more nematodes found in the bare ground followed by the grass.
Does the soil temperature affect the type of animals that live at those points?	The warmer the soil temperature, the more animals that were found there.
How does the distance from the pond affect the arthropods?	There are more arthropods farther away from the pond where there is more leaf litter.
How does vegetation cover affect soil temperature?	There was little to no affect on soil temperature due to vegetation on the study site.

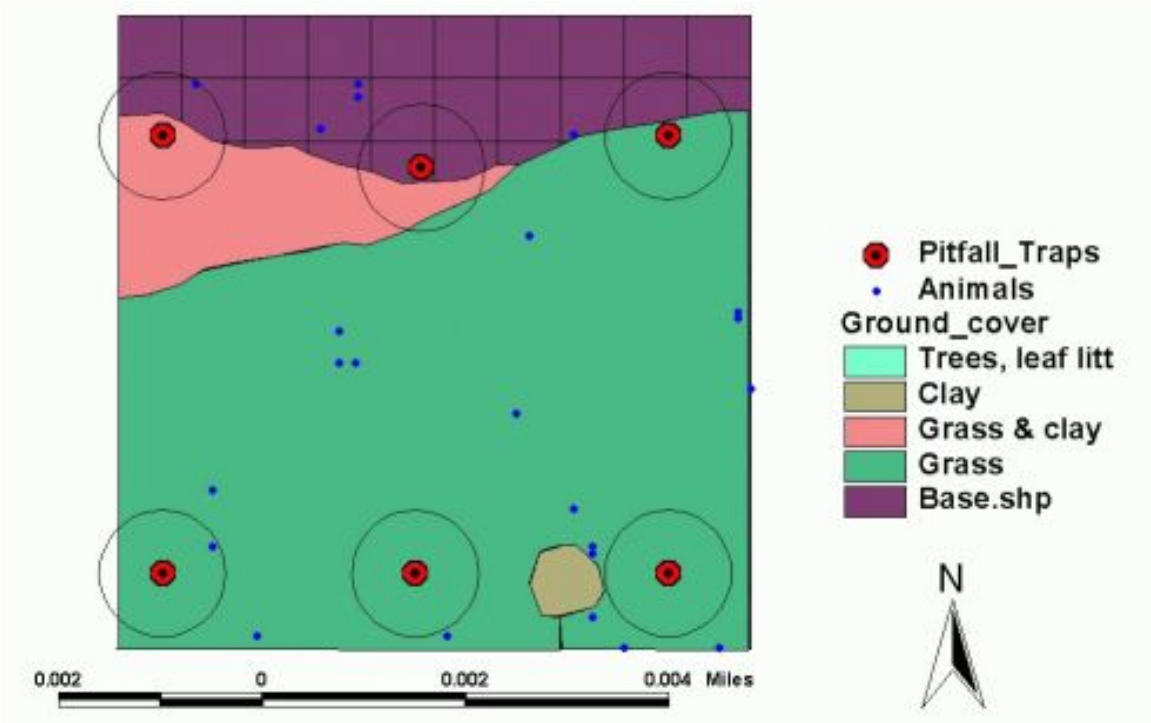
CARRINGTON MIDDLE SCHOOL CITYgreen GIS LAB GROUPS

PROBLEM QUESTION	CONCLUSION
What would happen if all the Bradford Pear trees at Carrington were replaced with Red Oak and Southern Magnolia trees?	The dominant tree on campus would become a red oak tree, which would improve wildlife benefits but carbon benefits, pollution removal benefits, and energy benefits would remain the same.
What would happen if the impervious surfaces increased by 70% and the trees decreased by 10%?	The carbon storage, pollution removal benefits and stormwater benefits decreased. If you want to make changes to the environment, you should consider the environment first.
How would the trees, carbon benefits, pollution removal benefits, stormwater runoff, and energy savings change if the study area were redrawn to include only the digitized area around the school?	The bare area decreased because we eliminated the bus lot. Stormwater benefits increased as a result. More trees should be planted around the school.
What would happen if 100%, 50%, and 25% of our trees died?	The air would not be as clean with fewer trees. We need to plant the trees we cut down due to building expansion.
What would happen if impervious surfaces increased by 75% and water by 50%?	The stormwater benefits and pollution benefits decreased. We suggest that impervious surfaces be limited at Carrington.
What would Carrington be like without trailers and instead there were trees?	More trees would save Carrington over $500 per year in carbon and air pollution benefits. A few trees make a big difference.
What would happen if 50% of the trees were cut down or destroyed?	Carbon storage was lower and runoff increased. This would contribute to global warming. There would be less food for wildlife.
What would happen if water increased by 2% and trees decreased by 50%	If water increases then there are fewer trees. There is a decrease in the tree savings and overall energy benefits. The number of species of trees also decreased.

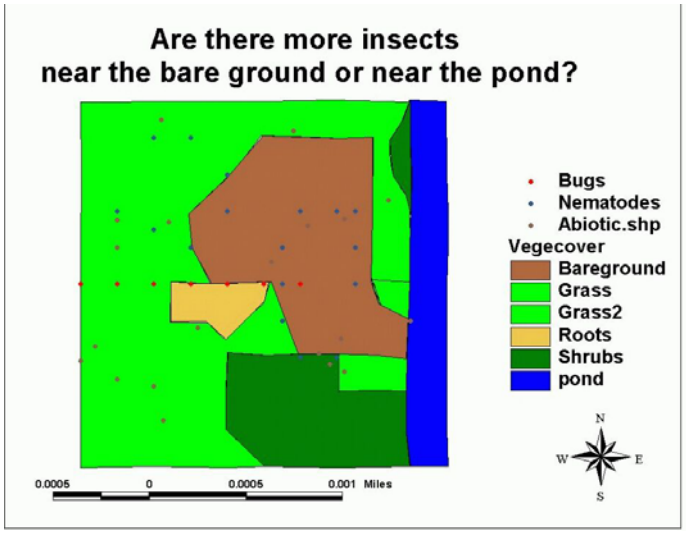
MOSS FINAL MAPS BY ANALYSIS SCORE

ANALYSIS SCORE OF FIVE

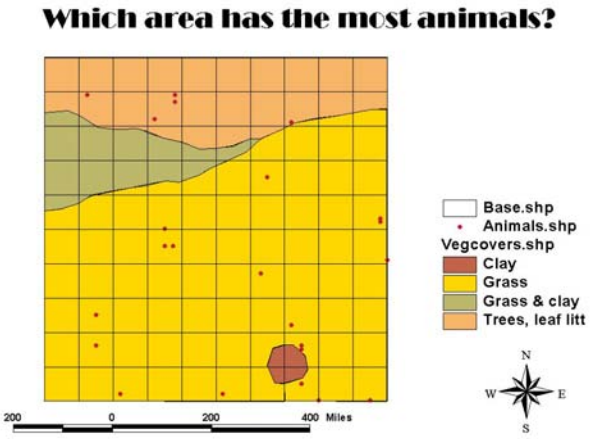
Does the temperature actually affect the number of insects that can be found or just their location?



ANALYSIS SCORE OF FOUR

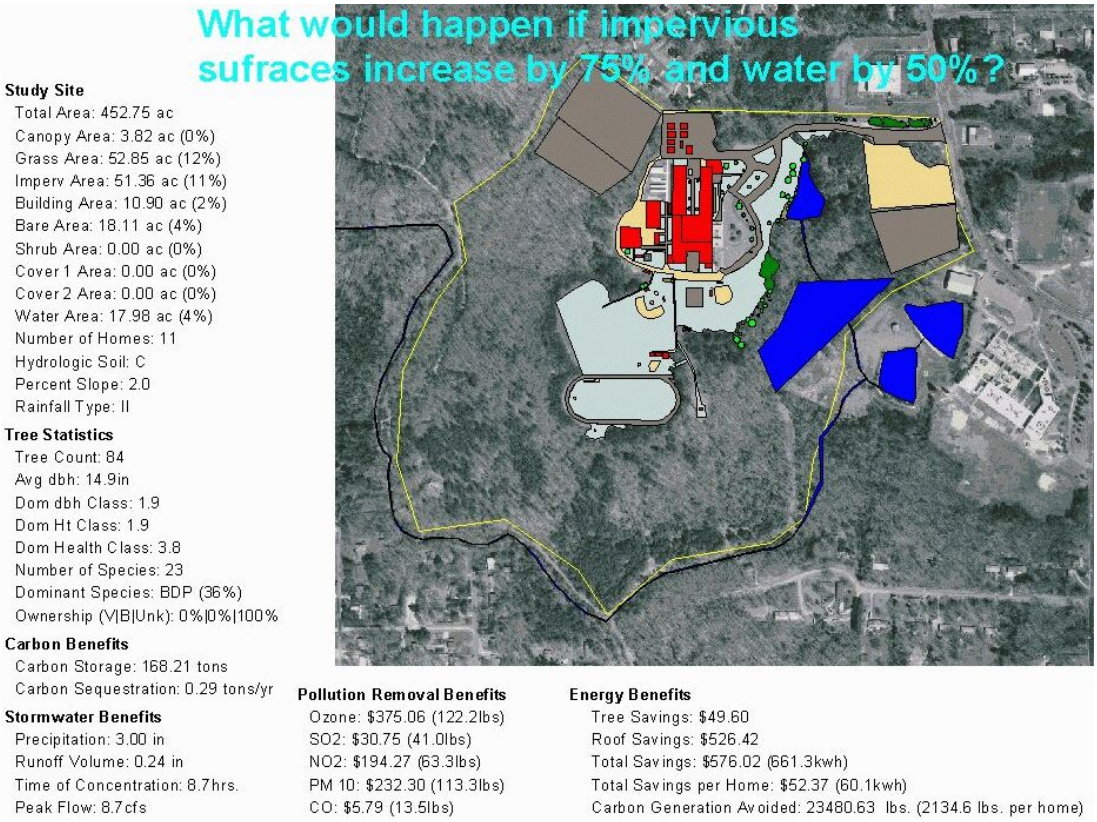


ANALYSIS SCORE OF TWO

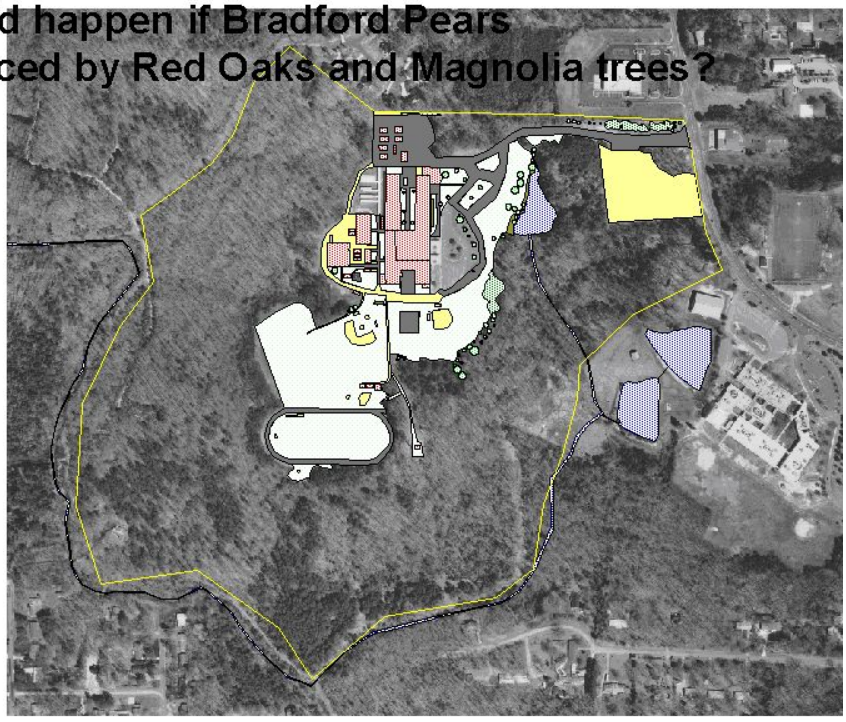


COMPARISON GROUP
CITYgreen GIS

ANALYSIS SCORE OF FOUR



ANALYSIS SCORE OF 3



Study Site
- Total Area: 452.75 ac
- Canopy Area: 3.82 ac (0%)
- Grass Area: 52.85 ac (12%)
- Imperv Area: 20.52 ac (5%)
- Building Area: 10.90 ac (2%)
- Bare Area: 18.11 ac (4%)
- Shrub Area: 0.00 ac (0%)
- Cover 1 Area: 0.00 ac (0%)
- Cover 2 Area: 0.00 ac (0%)
- Water Area: 3.33 ac (1%)
- Number of Homes: 10
- Hydrologic Soil: A
- Percent Slope: 2.0
- Rainfall Type: II

Tree Statistics
- Tree Count: 84
- Avg dbh: 14.9in
- Dom dbh Class: 1.9
- Dom Ht Class: 1.9
- Dom Health Class: 3.8
- Number of Species: 22
- Dominant Species: RO (20%)
- Ownership (V|B|Unk): 0%|0%|100%

Carbon Benefits
- Carbon Storage: 168.21 tons
- Carbon Sequestration: 0.29 tons/yr

Stormwater Benefits
- Precipitation: 3.00 in
- Runoff Volume: 1.29 in
- Time of Concentration: 13.8hrs.
- Peak Flow: 36.3cfs

06/28/03

Pollution Removal Benefits
- Ozone: $375.06 (122.2lbs)
- SO2: $30.75 (41.0lbs)
- NO2: $194.27 (63.3lbs)
- PM 10: $232.30 (113.3lbs)
- CO: $5.79 (13.5lbs)

Energy Benefits
- Tree Savings: $4.96
- Roof Savings: $52.64
- Total Savings: $57.60 (66.1kwh)
- Total Savings per Home: $5.76 (6.6kwh)
- Carbon Generation Avoided: 2348.06 lbs. (234.8 lbs. per home)

APPENDIX Q - MOSS/CITYGREEN WORKSHOP SCHEDULE

CONNECTIONS IN EARTH AND ENVIRONMENTAL SCIENCE
MAPPING OUR SCHOOL SITE USING MOSS AND CITYgreen GIS
www.ncsu.edu/scilink/studysite
Rita Hagevik, North Carolina State University, rita_hagevik@ncsu.edu

MONDAY

8:30 – 9:30 AM	Check-in, pre-assessments **(Meet each morning in room 1112)**
9:30 – 10:00	Introductions/Objectives/Expectations
10:00 – 10:30	**What is GIS?** **Guest Speaker: Charlynne Smith,** **Center for Earth Observation**
10:30 – 10:45	**BREAK**
10:45 – 11:45	Using ArcVoyager in your classroom: Volcanoes and Earthquakes and other ArcVoyager activities
11:45 – Noon	Share and discuss what is GIS and how it relates to your curriculum? – BEGIN curriculum and concerns chart paper
Noon – 1:00 PM	**LUNCH**
1:00 – 2:30	Using North Carolina Data in ArcView, Problem-Solving Activity NC CGIA Basin Pro
2:30 – 3:30	**Monitoring the Earth using Remote Sensing Images** **Guest Speaker: Charlynne Smith,** **Center for Earth Observation**
3:30 – 4:00	Class study area website and break up into groups for tomorrow Questions? Dress for outdoor lab work the rest of the week.

TUESDAY and THURSDAY are open lab times for you to work from 4:00 to 6:00 PM

TUESDAY

8:30 – 9:00 AM	Questions and concerns, Management strategies for outdoor lab work
9:00 – 9:30	Study Area procedures and teaching using a website
9:30 – 9:45	**BREAK**
9:45 – Noon	Begin study site data collection in groups
Noon – 1:00 PM	LUNCH
1:00 – 1:30	Overview of CITYgreen book
1:30 – 2:45	Demonstrate beginning CITYgreen project using NC State project Landsat TM Image and aerial photograph of your school Digitize trees NC State aerial photograph
2:45 – 3:45	**Trees and the Environment: Why are they important?** **Guest Speaker: NCSU College of Natural Resources**

3:45 – 4:00	Questions? Study site groups discussion of problem questions and possible additional procedures
4:00 – 6:00	**OPEN LAB TIME**

WEDNESDAY

8:30 – 9:00 AM	Questions and concerns, curriculum objectives, "wish list"
9:00 – 10:00	**Guest Speaker: Dr. John Meyer, entomologist, RM 1112 Identifying Ground Dwelling Insects and their Ecological Importance**
10:00 – 10:15	**BREAK**
10:00 – Noon	Collect pitfall trap data. Identify and categorize animals.
Noon – 1:00 PM	**LUNCH**
1:00 – 3:00	Begin additional procedure, build your own data sheet, add data to base map
3:00 – 4:00	Discuss problem questions and the study site projects, Midweek evaluation

THURSDAY

8:30 – 9:00 AM	Questions and concerns, demonstrate digitizing grasslands and impervious surfaces on NCSU CITYgreen project
9:00 – 11:00	Go outside and collect data on trees, grasslands, and impervious surfaces
11:00 – 11:15	**BREAK**
11:15 – 12:15 PM	**Guest Speaker: Dr. Ted Shear Forestry and Restoration, RM 1112**
12:15 – 1:15	**LUNCH**
1:15 – 3:15	Input data into NCSU CITYgreen project for trees, buildings, grasslands, and impervious surfaces
3:15 – 4:00	Complete study site projects, prepare maps of problem questions for group presentations tomorrow
4:00 – 6:00	**OPEN LAB TIME**

FRIDAY

8:30 – 9:30 AM	Present Study Site projects by groups
9:30 – 10:30	Using CITYgreen to run statistics
10:30 – 10:45	**BREAK**
10:45 – 11:45	Scenarios using CITYgreen
11:45 – 12:45 PM	**LUNCH**
12:45 – 2:00	Models using CITYgreen
2:00 – 3:00	Generate a management plan on how you will implement this project as part of your curriculum next year
3:00 – 4:00	Present management plans to group, continued support, final evaluations

MOSS FOLLOW-UP DAY AGENDA
Saturday
November 3, 2001

8:30 - 9:00 AM	Complete survey on your floppy disk
9:00 - 9:45	**GUEST SPEAKER: Shannon White, Raleigh Boys Club CITYgreen Project**
9:45 - 10:15	Georeferencing your study site to a digital aerial photograph and hotlinking
10:15 - 10:30	**BREAK**
10:30 - 11:00	Scenarios and modeling using CITYgreen
11:00 - Noon	Using handheld and GPS units to collect field data
Noon - 12:30 PM	Travel to Sci-Link
12:30 - 1:30	**LUNCH and NCURISA community meeting**
1:30 to 3:00	School presentations and sharing Discuss NCSTA presentation on November 15th from 11:15 to
3:00 to 3:30	What's next? Forms, evaluations, free materials

APPENDIX R - TEACHER MOSS/CITYGREEN WORKSHOP QUESTIONNAIRE

To what extent during the 2002-2003 school year have you made each of the following changes in your teaching practices as a result of the MOSS/CITYgreen workshop that you participated in.

To what extent have you……..		**Circle or mark one on each line**				
		Great Extent				**Not at all**
1.	Gained confidence is using and teaching with GIS in your classroom?	**1**	**2**	**3**	**4**	**5**
2.	Incorporate the MOSS unit into your classroom instruction?	**1**	**2**	**3**	**4**	**5**
3.	Incorporate the CITYgreen unit into your classroom instruction?	**1**	**2**	**3**	**4**	**5**
4.	Been able to have the GIS software installed on the computers at your school?	**1**	**2**	**3**	**4**	**5**
5.	Been able to present at conferences about your GIS activities?	**1**	**2**	**3**	**4**	**5**
6.	Been able to present at faculty, school or community meetings about your GIS activities?	**1**	**2**	**3**	**4**	**5**
7.	Implement or teach a course using GIS in your school?	**1**	**2**	**3**	**4**	**5**
8.	Implement or teach another unit using GIS?	**1**	**2**	**3**	**4**	**5**
9.	Create your own GIS curriculum?	**1**	**2**	**3**	**4**	**5**
10.	Create your own GIS project?	**1**	**2**	**3**	**4**	**5**
11.	Create a course using GIS for your school?	**1**	**2**	**3**	**4**	**5**
12.	Write and receive grants to use GIS in your school?	**1**	**2**	**3**	**4**	**5**
13.	Been able to attend other GIS college courses?	**1**	**2**	**3**	**4**	**5**
14.	Been able to attend other GIS workshops or conference presentations?	**1**	**2**	**3**	**4**	**5**
15.	Implement or teach another teacher in your school to use GIS for instruction?	**1**	**2**	**3**	**4**	**5**
16.	Implement or teach a GIS workshop to other teachers?	**1**	**2**	**3**	**4**	**5**
17.	Been able to use GIS as part of a project to apply for an award (Natl. Board, Kenan Fellow, others)?	**1**	**2**	**3**	**4**	**5**