TRADITION OR TECHNOLOGY?: THE IMPACT OF PAPER VERSUS DIGITAL MAP TECHNOLOGY ON STUDENTS’ SPATIAL THINKING SKILL ACQUISITION

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TRADITION OR TECHNOLOGY?: THE IMPACT OF PAPER VERSUS DIGITAL MAP TECHNOLOGY ON STUDENTS’ SPATIAL THINKING SKILL ACQUISITION

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DEDICATION

This dissertation is dedicated to my parents, Ruth Anne and Larry Collins, for always reminding me that I could do anything I wanted to do as long as I set my mind to it. Thank you for your endless love and support. I am eternally grateful for all that you both continuously do for me.
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This dissertation investigates whether spatial learning outcomes differ with respect to different instructional media. Specifically, it examines traditional, paper aerial imagery as compared to digital imagery visualized with 3D globes. Two research questions provided the focus: 1) Does spatial thinking skill development differ between analog (paper) and digital map media; 2) Does spatial thinking skill development differ based on attitudes toward geography, past travel experience, or demographic variables such as gender, and are there interaction effects among them related to the different media?

Spatial thinking skill development was measured as students received instruction using either paper or digital maps. Spatial thinking skills were tested pre- and post-lesson implementation via the Spatial Thinking Ability Test (STAT); sample tested skills included direction, distance, comparison, region, transition, pattern, and association. The research questions were investigated via a quasi-experimental (non-random) design involving classes of 8th grade middle school students.

This study determined that spatial thinking skill development does differ between the two types of media. Students taught by each media, both paper and digital, showed improvements in spatial thinking skills. Testing was based upon student condition (control group, digital instruction, and paper instruction), STAT question (each question requires specific spatial skills), and skill area (broad categories of spatial thinking skills included in the STAT). Overall, paper map instruction was found to
develop spatial thinking skills among students slightly better than digital map instruction when analyzing STAT score improvements by student condition and by STAT question. Although there were no statistically significant differences in any of the 8 skill areas when analyzing STAT score improvements by skill area, the digital map instruction showed improvements in more spatial thinking skill areas than the paper map instruction.

A small correlation was found between student spatial thinking acquisition and past travel experiences of students. Additionally, this study established a small correlation between student spatial thinking skill acquisition and student attitudes toward technology. There were also significant correlations found between student spatial thinking skill acquisition and academic levels. This study established that Honors students performed better than College Preparatory students.

This study has shown that both media, paper and digital, have their own benefits and weaknesses, but ultimately both assist in improving spatial thinking skill acquisition among students. Digital maps should be utilized in the K-12 curriculum, but not at the expense of the more traditional, paper map.
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CHAPTER 1

INTRODUCTION

“Given the need for increased scientific and technological literacy in the workforce and in everyday life, we must equip K-12 graduates with skills that will enable them to think spatially and to take advantage of tools and technologies – such as geographic information systems (GIS) for supporting spatial thinking” (NRC 2006, 13).

The ability to think in spatial terms is essential to the understanding of natural and cultural phenomena. Critical business, emergency preparedness, intelligence, and diplomatic decisions, among others, depend on spatial thinking. The economic competitiveness of the United States also depends on having a population that is spatially literate and can reason geographically. However, the results of the 2010 National Assessment of Educational Progress for Geography (The Nation’s Report Card) reveal this country’s severe inattention to geography education. Fewer than 30 percent of all students tested in 4th, 8th, and 12th grades scored at the “proficient” level or above. In the 12th grade alone, 79 percent of students tested are not proficient in geography and 30 percent do not even have a basic understanding of geography as seen in their inability to graph elevation on a contour map (NCES 2011). The Geo-Literacy Coalition urges that the alarming results in this report should “serve as a catalyst for increasing investment in educational programs in the geosciences in order to get our young people competent at thinking and working spatially” (National Geographic Society 2011, 1). Similarly, the National Research Council (NRC) argues for a systematic educational program to enhance levels of spatial thinking in K-12 students (NRC 2006). More recently, in
response to “the growing recognition among business leaders and policy makers that Americans lack the critical geographic understanding and reasoning skills that will be required for careers and civic life in the 21st century” (National Geographic Society 2013, 1), the Road Map Project is charting a course for large-scale improvement of K-12 geography education in the U.S. Additionally, Goldsberry contends that a recommitment to “a geography curriculum in both our high schools and universities will be crucial to effectively developing a generation of great data visualizers who can tackle our challenges” (2013, 1).

In the 1940’s, Harvard University eradicated its Geography Department, the only entire academic program the university has eliminated in its 375-year history. Many universities immediately followed suit and “seventy years later we are paying for a prolonged lack of spatial thinking at American universities. There are too few classes that enable learners to improve their spatial reasoning abilities, with maps and visualizations being of course the most central artifacts to such improvements. The problem is simple: not enough people know how to make maps or handle spatial data sets” (Goldsberry 2013, 1). However, these core competencies of geographic education have never been more relevant or necessary.

1.1 SPATIAL THINKING

According to the Geography Education Standards Project, enhancing spatial thinking is one of the key goals of geography education (1994). The importance of spatial thinking reached a level of prominence with the publication of the National Research Council Report Learning to Think Spatially (2006). Spatial thinking is one form of thinking that is defined as the knowledge, skills, and habits of mind to use concepts of
space (such as distance, orientation, distribution, and association), tools of representation (such as maps, graphs, and diagrams), and processes of reasoning (such as cognitive strategies to facilitate problem-solving and decision-making) to structure problems, find answers, and express solutions to these problems (NRC 2006). It is the concept of space that makes spatial thinking a distinctive form of thinking. Spatial thinking is universal and is used in everyday life as well as in academic and workplace settings. The National Research Council highlighted three different, yet interrelated, types of spatial thinking: thinking in space, thinking about space, and thinking with space (2006). Each type of spatial thinking promotes the other types of spatial thinking. Spatial thinking skills allow students to recognize and understand relationships in multiple ways and to remember them in both static and dynamic representations.

“Spatial thinking is a powerful tool. It is fundamental to problem solving in a variety of contexts: in life spaces, physical spaces, and intellectual spaces. In each case, it can offer increasingly powerful understandings, moving from description through analysis to inference. In each case, it depends upon a level of spatial knowledge, skills in spatial ways of thinking and acting, and the development of spatial capabilities. All of the component skills can, to some significant degree, be learned and this points to the crucial need for education in spatial thinking” (NRC 2006, 48).

1.2 GEOSPATIAL TECHNOLOGIES

One aspect of geography education is the use of geospatial technology. It is crucial that K-12 students learn how to use technology and reason spatially so that they are prepared to understand and address economic, political, and environmental issues at the local, national, and global scale. “As a consequence of the increasing availability of high-quality data, geospatial technologies are changing our capacity to understand the world, enhancing geography’s role as a practical problem-solving tool for individuals and
societies” (Heffron and Downs 2012, 10). Geospatial technology uses in education include global positioning systems (GPS), geographic information systems (GIS), remote sensing, and virtual globes such as Google Earth. While a literature on educational use of the first three has developed over the past two decades, there has been much less research on using Google Earth as an educational tool and evaluating its effectiveness on student learning. Researchers have described this time as being “ripe, if not overripe” for such studies (Montello and Freundschuh 2005; Patterson 2007; Montello 2009). Despite repeated suggestions that geographic information systems and virtual globes are unmatched for their ability to engage students in higher-level spatial thinking skills (Kerski 2008; Patterson 2007), there is little empirical evidence to suggest that paper maps – or traditional low-tech instructional delivery – fare worse. Herein we test this basic assumption by asking if students exhibit higher levels of mastery in spatial thinking via two different instructional media.

1.3 RESEARCH PURPOSE

This research investigates an existing resource, the South Carolina Maps and Aerial Photographic Systems program (hereafter SC MAPS), a standards-based interdisciplinary middle school curriculum. Originally developed with a set of satellite imagery, topographic maps, and other materials on paper, the SC MAPS program faces a new opportunity, namely integration with digital technologies. Free, off-the-shelf online programs such as Google Earth allow students visualization and analytic opportunities that were not available during the development of the SC MAPS program. What was previously innovative – the use of infrared and other satellite imagery to explore a range of physical and social issues – appears out of step with the rapid developmental pace of
newer geospatial representations such as three dimensional (3D) globes. However, the assumption that students learn equally well or better with these new technologies should not go unchallenged.

The digital revolution has immensely changed the way information is exchanged and thus disseminated to students. The Geography Education National Implementation Program (GENIP) has updated and refreshed the National Geography Standards (Geography for Life) since its first publication in 1994 in order to reflect two of the major changes in geography education: the development of geospatial technologies and the recognition that spatial thinking is central to geography. Standard 1 of the second edition of Geography for Life reads: “How to use maps and other geographic representations, geospatial technologies, and spatial thinking to understand and communicate information” (Heffron and Downs 2012, 21). Standard 2 continues by suggesting that a spatial understanding of environments will assist people in making sense of the world: “How to use mental maps to organize information about people, places, and environments in a spatial context” (Heffron and Downs 2012, 27). Additionally, Standard 3 calls for students to recognize spatial patterns and thus be able to examine why they exist: “How to analyze the spatial organization of people, places, and environments on Earth’s surface” (Heffron and Downs 2012, 31).

Furthermore, spatial thinking and geospatial technologies have been identified by the Road Map Project as critical areas of research in order to effectively improve geography education. Recommendation 4 calls for “research about fieldwork and its impact on learning geography knowledge, skills, and practices” with a particular emphasis on geospatial technologies (Edelson et al. 2013, 58). Recommendation 6 calls
for “interdisciplinary and multidisciplinary approaches, drawing on relevant research results…which has focused on the role of spatial thinking in STEM education” (Edelson et al. 2013, 59). Additionally, in Recommendation 3, the Geography Education Research Report calls for research “to investigate the characteristics of effective geography teaching” and a need “to identify what practices characterize effective geography teaching, how teachers’ pedagogical decisions impact student achievement and performance, and which instructional strategies promote and support geography learning most effectively” (Edelson et al. 2013, 58).

In this project we re-assess the SC MAPS program in light of these new technologies. Both approaches (paper v. digital) have their own benefits and weaknesses. For example, Google Earth-like products have extensive imagery for many places, but the quality is much better for urban areas. Images of rural areas often have poor resolution and infrared imagery is not included. Paper maps in the SC MAPS program contain infrared imagery allowing for unique change detection opportunities. However, these static images are quickly dated and not changeable. Virtual globes allow users to scale data, but only one or two students can use the computer at a time. SC MAPS products are not scaleable, but a group of students can cooperatively work together around these large, laminated maps. In sum, this research is straight-forward and asks a simple yet profound question: Are digital map technologies superior to paper representations for enhancing spatial thinking skills?

1.4 RESEARCH QUESTIONS

This introduction has provided a basic outline of the need to further understand how students better learn spatial thinking skills. This study will investigate whether
students better learn spatial thinking skills by receiving paper or digital map instruction. This study will also explore what other barriers may influence spatial thinking skill development, such as attitudes towards technology and geography, access to technology, and demographic variables such as gender. This research is driven by 1) a lack of student proficiency in geography content and skills; 2) inattention to the educational uses of digital globes; 3) the overwhelming need to improve spatial thinking skills among students; and 4) the need for research-based curriculum (re)development of the SC MAPS program. Two research questions are posed:

1. Does spatial thinking skill development differ between analog (paper) and digital map media?

It is expected that both instructional media will increase spatial thinking skill development in students. However, it is also anticipated that students who are taught using paper maps will have a higher increase in spatial thinking skills than those students taught with digital map instruction. This expectation is based on the findings of Pedersen, Farrell, and McPhee (2005), which demonstrate that while digital maps are effective, they are not more effective than paper maps. Furthermore, Meyer et al. (1999) argue that learning the technology in a K-12 setting often undermines or takes the place of learning about geographical and spatial analysis. Similarly, Cunningham (2005) argues that while GIS is an essential technology, manual pen and ink mapping is the best tool for geographic learning. This expectation is further supported by Hurst and Clough (2013), Verdi et al. (2003), and Pedersen, Farrell, and McPhee (2005), which have established that there is a greater preference for paper maps by both geographic experts and students. However, it is important to note that there could be a generational bias in these studies as
they were completed by “Digital Immigrants” rather than “Digital Natives” (Prensky 2001). These issues will be discussed in the limitations of the study in Chapter 7.

2. Does spatial thinking skill development differ based on attitudes toward geography, past travel experience, or demographic variables such as gender, and are there interaction effects among them related to the different media?

Many variables may contribute to how a student best learns spatial thinking skills. This research question investigates whether variables beyond instructional media have a role in spatial thinking skill development. It has been demonstrated that geospatial technologies improve student attitudes, motivation, and achievement in geography learning (Keiper 1999; Baker and White 2003; West 2003). Therefore, it is expected that the more favorable the student attitudes towards geography, the higher the spatial thinking skill development will be. Thorndyke and Hayes-Roth (1982) and Golledge (1999) found that spatial learning with direct, navigational experience is more successful than map learning. Based on these findings, it is also assumed that more past travel experience in students will equate to higher spatial thinking skill development. In addition, it has been shown that gender differences in spatial thinking ability favors males over females (Boardman 1990; Goldstein, Haldane and Mitchell 1990; Casey et al. 1995). A similar finding reports that males know more about geography careers than girls and that the gender gap in geographic knowledge increases with grade level (LeVasseur 1999). Additionally, Hardwick et al. (2000) establish that persons who identify themselves with stereotypical male traits such as assertiveness and independence scored better on a basic test of geographic knowledge than persons who identify themselves with stereotypical female traits such as gentleness and sensitivity. Based on this previous
research it is also anticipated that males will develop better spatial thinking skills and improve upon existing skills better than females.

Both questions are investigated via a quasi-experimental (non-random) design involving classes of middle school students. Spatial thinking skill development will be measured as students participate in either paper-based or digital map-based instruction.

Ideally “the geographically informed person knows and understands the world in spatial terms, that is; how to use maps and other geographic representations, tools, and technologies to acquire, process, and report information about people, places, and environments in a spatial context; and how to analyze the spatial organizations of people, places, and environments on earth’s surface” (GESP 1994). Research has shown that “well designed instructional materials that engage the spatial-thinking parts of a student’s brain usually result in higher reading and math scores, as well as better performance in other subjects like history, earth science, and economics. Reducing the amount of time spent on geography…may actually reduce math and reading scores” (Gersmehl 2008, 99). This research furthers our understanding of how best to approach and foster these skills with students and ultimately create curriculum and materials to achieve those goals.

1.5 OVERVIEW OF DISSERTATION

This dissertation is organized into seven chapters. Chapter 1 provides an introduction to spatial thinking, geospatial technologies, and the challenges they both present in contemporary geography education. It also poses the research questions that guide this study. Chapter 2 continues this background by reviewing the literature on spatial thinking and geospatial technologies in geographic education. The research design
and methods are discussed in Chapter 3, as well as the demographic data of the study population.

Chapters 4, 5, and 6 comprise the results of the research. Chapter 4 specifically reports on the quantitative results by investigating in detail the student scores and the different media in the study. Chapter 5 examines the qualitative aspects of the study by focusing on the responses from the student and teacher surveys. Chapter 6 is a discussion of the findings that links the quantitative and qualitative results together for a more comprehensive evaluation. Chapter 7 consists of conclusions and opportunities for further research.
CHAPTER 2

LITERATURE REVIEW

In the previous chapter, a small set of literature was reviewed to introduce the severely low levels of competency with basic geographic concepts among students in the United States and the widespread concern among geography educators for a grave need for geographic literacy. The following review of literature elaborates further by detailing the concept of spatial thinking and the increasing need for students to possess these skills. Additionally, geospatial technologies are explored as an integral part of contemporary education as the research focuses on whether or not these technologies are more effective for student learning in the classroom.

Geospatial technologies and spatial thinking have emerged as an increasingly indispensable part of contemporary life and understanding them has become vital to everyday activities, as well as, a crucial component of many career fields including science, math, social science, business, public health, urban planning, and engineering (Nielson et al. 2011). The value of these technologies far outreaches the technology itself, as the National Research Council (2006) reports that geospatial technologies actually promote spatial thinking. The national standards in science, geography, and technology education call for widespread use of inquiry-based learning throughout the K-12 curriculum (NSTA 2013; Heffron and Downs 2012; ISTE 2007). Within this standards-based instruction, one geospatial technology, GIS, “is emerging as an instructional technology for supporting contextually rich student learning” (Baker 2005).
Despite the values that accompany geospatial technologies, its implementation to support K-12 curriculum has been limited at best. Most classroom use of geospatial technologies promotes learning in other areas such as in geography, science, and math rather than using geospatial technologies to specifically engage students in spatial thinking (Furner and Ramirez 1999; Moxey et al. 2004; Shin 2006, and Nielson et al. 2011). This project seeks to learn which medium, paper maps or geospatial technologies, might be more effective in the development of spatial thinking skill acquisition among students.

2.1 GEOGRAPHY EDUCATION

Early geographic education was largely applied and functional by observing Earth and its features and addressing such issues as when to plant crops, where to hunt, and how to find one’s way over distances. Although its position throughout history varied relative to political, social, and historical trends, geography education has remained an essential base of societal knowledge as it has evolved both as a discipline and an educational subject (Stoltman 2006). Drawing upon both scientific and educational theories, geography education has transformed from a teacher-directed, regionally emphasized discipline to one that is more research-based with an emphasis on spatial relationships. Over the past decade, there has been increased emphasis and quantity of research in geography education and of geography’s role in education for responsible citizenship, as well as a renewed interest in the environmental protection (Stoltman 2006). Bednarz and Bednarz assert that geography educators also can make contributions through geographic information science by seeking “the most effective way to convey information about spatial patterns and relationships and to make the power of geographic
technologies useful to non-specialists” (2004, 25). Several scholars argue that geospatial technologies facilitate spatial thinking and problem-solving skills (Demers 1999; Baker 2005; and NRC 2006). Heeding this call, this project tests whether geospatial technologies better enhance student achievement and comprehension.

Positioned as part of the social studies curriculum, geography education has often taken a minor roll within its setting (Gritzner 2003). In many instances, geography education has been limited to memorizing decontextualized facts such as place names of capital cities and environmental superlatives such as the longest river or the highest mountain rather than learning about why things are located where they are and understanding the spatial relationships between different phenomena. Heffron, co-editor of the second edition of the National Geography Standards, notes “there is little value in memorizing content knowledge if students are not able to apply this knowledge and put it to work investigating and solving challenges” (2012, 44). The ability to think critically and in spatial terms is becoming a requirement to be an effective citizen in contemporary society. Helping students understand spatial information presented in both printed and digital format “places a new – but welcomed – burden on geography educators to ensure that map learning and spatial thinking are taught and taught well in the social studies” (Bednarz, Acheson, and Bednarz 2006, 400).

2.2 STUDENT LEARNING IN GEOGRAPHY

Geography educators have long been interested in the most appropriate ways to teach and learn geography. This interest has been guided by a special focus in the teaching and learning of map skills. Bednarz, Acheson, and Bednarz (2006) assert that maps do not constitute the whole of geography, but rather geography cannot exist without
them. How the student processes map information is fundamental to geography and has been seen in the shift in research paradigms towards cognitive processes (Lobben et al. 2014; Slocum 1999). In order to discover the most appropriate and meaningful ways of teaching geography, student learning must be investigated.

Bloom’s Taxonomy was created in an effort to promote higher forms of thinking in education, rather than simply rote memorization (Bloom 1956). Three types or domains of learning were identified: the cognitive domain, the affective domain, and the psychomotor domain. The cognitive domain involves knowledge and the development of intellectual skills; the affective domain involves growth in feelings or emotional areas such as feelings, values, appreciation, enthusiasms, motivations, and attitudes; the psychomotor domain involves manual or physical skills, which include physical movement and coordination (Bloom 1956). It is within the cognitive domain of learning where most educational research has taken place about student learning. Bloom’s learning taxonomy (1956) was developed with behaviors extending from the simplest to the most complex: knowledge, comprehension, application, analysis, synthesis, and evaluation.

A major model of cognitive development is Piaget’s stages of development. He contends that thinking develops in a series of stages and each stage is associated with a mental age. Specifically, it is argued that children who are in the pre-operational stage cannot handle basic operations required for spatial cognition and behavior (Piaget and Inhelder 1956). According to Piaget, the pre-operational stage occurs from two years of age to seven years of age and is characterized by the development of thought processes and vocabulary.
Blaut and Stea (1971) were among the first to provide empirical evidence that young children of school-entering age can learn map skills. Boardman (1990) contents that the mapping abilities among young children have been underestimated and in fact they are able to draw from memory sketch maps from the area surrounding their homes. Blaut (1997) critiques the works of Downs and Liben for their position in which he states, “Piagetian Theory, in their view, explains why young children can’t learn very much about maps (1997, 153).” In a response to Blaunt’s characterizations, Liben and Downs (1997) reaffirm their position that map understanding begins at an early age, but progresses through a gradual and often difficult development process. They argue that this process is much too complex to conclude whether or not map understanding can be reduced to the rhetoric of “Can-ism versus Can’tianism” (Liben and Downs 1997). “It is not enough for the child to produce a correct answer. It is also important to probe the child’s reason for that answer. If children ‘know’ that north is at the top of the page because north is always at the top of the page, they do not understand the notion of north and viewing azimuth” (Liben and Downs 1997, 165). Despite the debated quantity and quality of what constitutes “understanding,” these scholars can agree that there is in fact some understanding and learning of maps at an early age.

Over the past few decades, educational thinking has been largely unchallenged in its move toward more active forms of student learning such as collaborative, experiential inquiry-based, problem-solving approaches (Laurillard 2013). Two important educational goals are student retention and student transfer, whereas retention requires the student to remember what they have learned and transfer requires the student to make sense of and use what they have learned (Anderson et al. 2001). The resulting learning
outcome of retention and transfer is identified as meaningful learning (Anderson et al. 2001). In an effort to produce more meaningful learning and expand cognitive processes in the curriculum, Anderson et al. (2001) revisited the cognitive domain of Bloom’s Taxonomy and redeveloped the names of the behaviors by changing them from nouns to verbs, as well as, slightly changing the order of the behaviors. The new cognitive domain taxonomy reflects a more active approach to learning: remembering, understanding, applying, analyzing, evaluating, and creating (Anderson et al. 2001).

“Learners are assumed to be active agents in their own learning; they select the information to which they will attend and construct their own meaning from this selected information. Learners are not passive recipients, nor are they simple recorders of information provided to them by parents, teachers, textbooks, or media. This move away from passive views of learning toward more cognitive and constructivist perspectives emphasizes what learners know (knowledge) and how they think (cognitive processes) about what they know as they actively engage in meaningful learning” (Anderson et al. 2001, 38).

One example of such meaningful learning is project-based learning (PBL). Project-based learning, first initiated by John Dewey as “learning by doing”, is an educational technique that engages students in learning through activities that require creative problem solving and applied knowledge rather than lecture and recitation. Camp (1996) identifies advantages to PBL as improving factual retention, transfer of concepts, and self-directed learning. Scholars proclaim that PBL can promote a rich student learning environment (Bednarz 2000; Bednarz 2001; Baker and White 2003; King 2008;
Liu and Laxman 2009; Liu et al. 2010; Demirci et al. 2011). Furthermore, Bednarz (2000) asserts that when accompanied with appropriate educational technology, the PBL model offers the best media for teaching and learning science process skills and content. Schacter and Fagnano (1999) claim that to produce more meaningful learning, technology use in the classroom needs to be designed according to sound learning theories and pedagogy. Pedagogy helps guide the learner to learn. “The emphasis is still on pedagogy leading the use of technology, rather than adapting to what technology offers” (Laurillard 2013, xvi). According to Goldstein and Alibrandi (2013), GIS is an educational technology that activates students’ multiple intelligences. Gardner’s multiple-intelligences theory contends that intelligence is not uniform and that people possess at least eight intelligences which include musical, bodily kinesthetic, logical mathematical, linguistic, spatial, interpersonal, intrapersonal, and naturalistic (Gardner 2004). “These intelligences, which influence the various ways in which learning is absorbed, retained, and transferred, are activated by using GIS through reading (linguistic intelligence), mapping (spatial intelligence) and analysis (logical-mathematical intelligence)” (Goldstein and Alibrandi 2013, 69). It is primarily the goal of this study to explore this identified spatial intelligence and investigate whether or not the type of media used in the classroom better promotes this type of learning. Both paper and digital instructional media are delivered to the student by direct instruction through different mediums. The digital instruction is enhanced with technology whereas the paper instruction is not.

2.3 THE CONCEPT OF SPATIAL THINKING

“Without geography – or any teaching that emphasizes spatial thinking – the focus will remain on the data, and that’s a mistake. Yes,
data are undeniably important but they are not holy. Data are middlemen. Even the term “data visualization” overemphasizes the role of the middleman, and mischaracterizes the objective of the activity. Nobody wants to see data; nobody learns from that. The best visualizations never celebrate the data; instead they make us learn about worldly phenomena and forget about the data. After all, who looks at the Mona Lisa to think about the paints?” (Goldsberry 2013, 1).

Many researchers contend that a better understanding of cognitive processes can improve geography education at all ages and developmental levels. Spatial thinking is a universal mode of cognitive processing related to the internalization, transformation, interpretation, and analysis of data that is spatial or visual in nature, or has been “spatialized” in order to clarify complex data relationships (e.g., population pyramids or using maps to display spatial distribution of cancer rates). Put simply, spatial thinking is the ability to visualize and solve problems spatially. Spatial thinking skills are multifaceted in their use and combine concepts of space (the ability to understand the meaning of space and spatial relationships), tools of representation (such as internal and external spatial representations like printed maps, cognitive maps, and written directions, and processes of reasoning), and the ability to manipulate, organize, interpret, and structure spatial information (National Research Council 2006). Furthermore, “in terms of its power and its pervasiveness, spatial thinking is on par with, although perhaps not yet as well recognized and certainly not as well formalized as, mathematical or verbal thinking…” (NRC 2006, 25).
Gersmehl (2008, 98) defines spatial thinking simply as “thinking about locations and relationships in space.” Spatial thinking skills are used by everyone in everyday life and developed at an early age (Piaget and Inhelder 1956; Blaut and Stea 1971; Boardman 1990; Blaut 1997; Liben and Downs 1997). These skills include recognizing patterns in data and understanding changes over space versus changes over time. Spatial thinking helps us to identify, remember, understand, and make decisions about the relationships between objects represented in space and the spatiotemporal and thematic attributes of the natural and human features and events occurring there (Montello 2008; Kulo and Bodzin 2011). Importantly for education, “considering how people learn about space and how they deal with the spatial aspects of their environment on a daily basis will allow us to devise maps, and map presentation strategies, that facilitate thinking and problem solving rather than memorizing” (MacEachren 1991, 156).

As a whole, our view of the world is constructed by our perception and cognition. Basic spatial thinking and reasoning skills affect these perceptions. Our spatial perception, visualization, and orientation is typically defined as our spatial ability and is a much narrower concept than the cognitive processes of spatial thinking (NRC 2006). In order to deal with even simple interactions an individual must deal with problems of scale, location, magnitude, distance, direction, orientation, and other spatial concepts that help make sense of the often, incomplete information with which we are presented. On a basic level, spatial thinking helps us identify and remember locations, directions, and to identify the basic spatial patterns (e.g., land use) that define our environment. On a broader level, it is important for integrating our knowledge of the environment with other information in order to explain spatial patterns and hypothesize about where something
might be located and why. It also helps us to understand the relationships between humans and the environment, geographic patterns, and schematic diagrams.

It is important to note that methods of spatial thinking and reasoning are broadly applicable and are not restricted to information that is inherently spatial. The ability to spatialize information allows for the examination of patterns and trends that would otherwise not have been readily apparent from the raw data. For example, showing the number of malaria cases by country would certainly disclose that certain countries have higher amounts of malaria cases than other countries. However, when this data is spatially represented, it will show that the number of malaria cases is highest in countries located in the tropics. While spatial thinking is most often linked to visual modes of representation or reasoning, it also extends to other sensory systems including olfactory, tactile, and auditory. One example is the ability to know where to look for a bird after hearing its call even if the bird is not visually apparent; another example is being able to identify change in location or land use by noting texture of the ground surface (e.g., pavement vs. brick or walkways vs. grass).

The basic skills for thinking and reasoning spatially are innate in everyone (Egenhoffer and Mark 1995). Using this set of skills people are able to survive in a complex environment, however, they may not be functioning at their highest capability if they have not developed further than a basic, naïve understanding of spatial relationships. Many educators believe that we can improve existing and develop new spatial thinking and reasoning skills through practice, and there is substantial need for learning materials that can aid in this process. Several disciplinary education standards, either directly or
indirectly, emphasize the importance of spatial thinking and reasoning (Anthamatten 2010; NRC 1999; Geography Education Standards Project 1994).

Spatial thinking and reasoning skills develop in a cumulative nature, with each additional skill serving as a building block to understand new concepts (Golledge 1995; Golledge, Marsh, and Battersby 2008). Mastery of these basic spatial thinking skills early in life provides a solid foundation for continued development throughout life. This skill development is of interest for the STEM disciplines, as spatial thinking is deeply rooted in each (National Research Council 2006). This does not mean that spatial thinking is the only way of thinking that is relevant to these fields, but that it plays a critical role in understanding and problem solving in these fields. For example, studies in a variety of disciplines have linked spatial thinking and reasoning skills to the development of geometric thought (Saads and Davis 1997), the ability to conceptualize three-dimensional features (Siemankowski and MacKnight 1971), and in predicting success in the sciences at the elementary school and college level (Poole and Stanley 1972; Guay and McDaniel 1977; Pallrand and Seeber 1984; Bednarz 2000; NRC 2006).

Common to all of these examples is visualization. Visualization is thought to play an important role in scientific problem solving (Piaget and Inhelder 1966; Hegarty and Kozhevnikov 1999; Uttal 2000; Kosslyn 2002). The importance of visualization in the work of scientists such as Einstein, Feynman, and Faraday – just to name a few – has been noted repeatedly (see Ferguson 1993; Feynman 2001; Roth 1992). Some visualizations are physical models of spatial relationships, such as maps, schematic diagrams, animations, photographs, or other graphic representations; others are created internally as part of the problem solving process, such as cognitive maps or other
imagined spatial representations. These visual representations often help explain processes that could not otherwise be easily understood (Larkin and Simon 1987). While this mode of thinking is beneficial in many problem-solving environments, it may not be used if an individual is not practiced in it. Knowing how and when to use visual-spatial thinking skills must be developed in some individuals. Asking learners spatial questions “involves knowledge and understandings of spatial concepts, the ability to flexibly use that knowledge, the skills and habits of mind to utilize tools of representation, and the reasoning to solve problems and make decisions” (Jo, Bednarz, and Metoyer 2010, 51).

The basic ability to read and create visual representations is critical, but it is also necessary to be able to interpret patterns and processes shown in these visualizations. What specific visual-spatial thinking skills are critical? Janelle (2007) suggests eight foundation concepts in spatial thinking for the STEM disciplines: location, distance, network, neighborhood and region, scale, spatial heterogeneity, spatial dependence, and objects and fields. These foundation concepts are applicable to all of science (physical and social). The first two concepts, location and distance, are “primitives” of spatial thinking (Golledge 1995), without which we cannot assess any spatial relationships; they allow us to define, search for, and identify simple patterns or spatial relationships – such as identifying clusters or groups of like values. Once patterns can be identified, the focus switches from simple identification to the more complex processes of interpretation and explanation relying on the remaining six concepts. The more advanced spatial thinking concepts require application of critical thinking skills to help identify formal models to explain spatial relationships, such as distance decay models or shortest/optimum paths, or understanding complex spatial patterns.
Scholars currently debate how spatial thinking skills are separately distinguished from each other (Gersmehl 2008; Golledge, Marsh, and Battersby 2008; Jo and Bednarz 2009); much less debated is the need for the inclusion of spatial thinking in the K-12 curriculum (National Research Council 2006). A number of spatial thinking skills have been recognized that foster problem-solving and analytical skills in the classroom (Gersmehl 2008). These include:

a. comparison (comparing one place with another)

b. aura (describing the influence that a place can have on neighboring locations)

c. region (drawing a line around all places that have similar characteristics or are linked together in some way)

d. transition (describing what happens between two places with known conditions)

e. analogy (finding places that have similar positions and therefore have similar conditions)

f. hierarchy (identifying a spatial hierarchy, or how ‘nested’ features relate to one another)

g. pattern (describing the arrangement of features or conditions in an area)

h. association (identifying the extent to which features have the same map pattern)

A subset of these spatial thinking skills (Gersmehl 2008) such as aura, comparison, transition, and association were paired to the existing curricula and assessed via the different media (paper instruction versus digital instruction). Other spatial skills such as
identifying geographic features as points, lines, or polygons; location; direction; distance; and mentally visualizing 3D images based on two dimensional (2D) information were also included.

2.4 SPATIAL THINKING ASSESSMENT

Although there has been a growing amount of recent research in the context of spatial thinking, there has not been a significant amount of research and development of instruments to assess student spatial thinking skills. Downs (1994), as cited in Huynh and Sharpe (2013), argues that geography education research would benefit from producing an instrument to assess student performance. However, despite the importance and universality of thinking spatially, the National Research Council (2006) reports that its characteristics and implications for geography education are not well understood. Furthermore, they report that there are few instruments that have been tested for reliability and validity to measure spatial thinking skills within the discipline of geography. Spatial thinking has been researched and tested predominantly in the disciplines of psychology and geography. A variety of instruments have been used such as psychometric scales and intelligence tests (Gardner 1993; Liben 2002; Liben, Kasten, and Stevenson 2002), cognitive ability tests (Battersby, Golledge, and Marsh 2006; Marsh, Golledge, and Battersby 2007, and Golledge, Marsh, and Battersby 2008; Lee and Bednarz 2009), a paper-pencil test involving visual manipulation (Newcombe 2010), a spatial knowledge and thinking about locations quiz (Dunn 2011), and a geospatial thinking test (Huynh and Sharpe 2013).

There are a number of assessments that have been developed, but only one is a standardized instrument integrating geography content knowledge and spatial skills that
has been tested for reliability and validity. The Spatial Thinking Ability Test (STAT) (Lee and Bednarz 2012) was designed to assess individual’s growth in spatial thinking skills. More specifically, it was created to assess the spatial thinking components identified in the structures and hierarchies proposed by Gersmehl and Gersmehl (2005) and Golledge et al. (2002). The test did not include questions that addressed Janelle and Goodchild’s components of spatial thinking as it was developed before their work was available, however their work is similar to works of those that were used as seen in the summary of skills shown in Table 2.1 (Bednarz and Lee 2011). The rows in Table 2.1 show comparisons of similar skills across the three spatial thinking skill models. This instrument was chosen over other spatial skills measurement assessments for its reliability and validity and its results served as the spatial skills baseline prior to the SC MAPS/Google Earth intervention.

Table 2.1 Spatial Thinking Concepts (Adapted from Bednarz and Lee 2011).

<table>
<thead>
<tr>
<th>Gersmehl &amp; Gersmehl</th>
<th>Golledge et al.</th>
<th>Janelle &amp; Goodchild</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>Identity</td>
<td>Objects and Fields</td>
</tr>
<tr>
<td>Location</td>
<td>Location</td>
<td>Location</td>
</tr>
<tr>
<td>Connection</td>
<td>Connectivity</td>
<td>Network</td>
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<td></td>
<td>Distance</td>
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<td></td>
<td>Scale</td>
<td>Scale</td>
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<tr>
<td>Comparison</td>
<td>Pattern Matching</td>
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<tr>
<td>Aura</td>
<td>Buffer</td>
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<tr>
<td>Region</td>
<td>Adjacency, Classification</td>
<td>Neighborhood and Region</td>
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<tr>
<td>Hierarchy</td>
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<td></td>
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<tr>
<td>Transition</td>
<td>Gradient, Profile</td>
<td></td>
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<tr>
<td>Analogy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pattern</td>
<td>Coordinate, Pattern, Arrangement, Distribution, Order, Sequence</td>
<td></td>
</tr>
<tr>
<td>Spatial Association</td>
<td>Spatial Association, Overlay/Dissolve, Interpolation</td>
<td>Spatial Dependence, Spatial Heterogeneity</td>
</tr>
<tr>
<td></td>
<td>Projection, Transformation</td>
<td></td>
</tr>
</tbody>
</table>
2.5 GEOSPATIAL TECHNOLOGIES IN THE CLASSROOM

Computer technology is impacting the way that classroom instruction is taking place. Multiple learning pathways now complement traditional classroom instruction. These include television, video games, and the World Wide Web (Patterson 2007). Forer and Tan (1998) assert that one question still remains largely unanswered when it comes to using technology in the classroom: does technology in the classroom enhance learning? However, since that time, there have been multiple documented successes that technology does in fact enhance student learning (Demers 1999; Furner and Ramirez 1999; Keiper 1999; Baker and White 2003; West 2003; Wiegand 2003; Moxie et al. 2004; Baker 2005; Shin 2006; NRC 2006; Milson and Earle 2007). If technology use in the classroom does enhance learning, then does it do it better than traditional methods of instruction?

Unfortunately, the globe and the wall map are no longer “functional representations but decorative symbols of a well-furnished classroom” (Downs 2004, 183). But in their place is a new opportunity: computerized geospatial information with a different set of tools to support thinking spatially. How learning changes as a result is understudied as Mark et al. (1999, 761) note:

“As society makes transition to digital worlds, associated metaphors for geographical detail are likely to change also. Metric scale or representative fraction, the measure of geographical detail dominant in the cartographic world, has no well-defined meaning in a digital world of seamless perspectives on geography in which the user is free to zoom and pan at will. Other metaphors, such as the view from space, may replace metric
scale with less familiar dimensions such as the distance of the viewpoint from Earth.”

Career opportunities and civic participation are other important outcome considerations as we construct new digital learning environments. Bednarz, Acheson, and Bednarz (2006) argued that the ability to use images and spatial technologies intelligently and critically is becoming a requirement to participate effectively as a citizen in modern society. Additionally, the *Geographic Information Science and Technology (GIS&T) Body of Knowledge* aimed to guide curriculum development in response to the rising demand for better preparation of students for the expanding geospatial workforce (DiBiase *et al.* 2006). The U.S. Department of Labor has identified geo-technology along with nanotechnology and biotechnology, as one of the three most important and emerging fields (Gewin 2004). Furthermore, there is a surging demand for a proficient labor force in geospatial technologies as the Employment and Training Administration identified geospatial technology as a “high growth” industry with an inadequate supply of professionals (U.S. Department of Labor 2005). “The need for these tools and skill sets for global change, homeland security emergency response, and natural hazard mitigation applications will result in the further growth of GSTs (geospatial technologies) and a heightened demand for employees who possess expertise in this area” (Nielson, Oberle and Sugumaran 2011, 61). Although the geospatial field is very diverse and is expanding at an unprecedented rate, it is estimated that nearly 340,000 additional professionals will be needed in the workforce over the next ten years (DiBiase *et al.* 2010).

Geospatial technologies are a specialized subset of information technologies that handle geo-referenced data. Geospatial technology uses in education include, but are not
limited to smartphone and tablet applications, global positioning systems (GPS), geographic information systems (GIS), remote sensing, photogrammetry, and virtual globes such as Google Earth. There are a multitude of technologies available in each of these categories and many are available online at no cost. Additionally, these technologies are available to students and teachers in all disciplines across the curriculum. However, although geospatial technologies have become increasingly popular and are widely used, the integration of these technologies into the K-12 classroom has been startlingly slow (Baker and Bednarz 2003; Milson and Roberts 2007). Some of the reasons that have been speculated as the reasons for this slow adoption of geospatial technologies include a dearth of research on its effectiveness, a shortage of related curricula, software complexities, school technology limitations, scarce teacher training opportunities, and teachers’ lack of comfort in teaching with geospatial technologies (Bednarz and Audet 1999; Kerski 2003; Baker 2005; Bednarz and van der Schee 2006; Milson and Roberts 2007; Doering and Veletsianos 2007).

Many researchers suggest that geospatial technologies, such as geographic information systems (GIS) and virtual globes, are superior tools for teaching and learning spatial thinking and reasoning skills (Bednarz 2001, 2002; Kerski 2003; Baker 2005; Golledge, Battersby, and Marsh 2006; Goodchild 2006; National Research Council 2006; Marsh, Golledge, and Battersby 2007; Schultz, Kerski, and Patterson 2008; Nielsen, Oberle, and Sugumaran 2011; Henry and Semple 2012; Goodchild 2012; Goldstein and Alibrandi 2013). For example, Goldstein and Alibrandi (2013) document that the inclusion of GIS in middle school classrooms enhances student learning and student
achievement on standardized test scores in reading as well as final course grades in science and social studies.

Though this suggestion has been repeated through the literature, there has been little empirical testing of the supposed advantages of geographic technologies over low-technology media for teaching spatial thinking and reasoning skills. In fact, Dermici (2011) reveals that implementing GIS exercises in a classroom with one teacher using only a single computer to demonstrate is an effective teaching and learning method. In an effort to serve resource-poor schools, an even more low-tech example demonstrates that paper-based GIS educational packages provide an adequate alternative to computer-based GIS teaching methods (Breetzke, Eksteen, and Pretorius 2011). Furthermore, having access to a map or having access to a computer is not the same as “doing geography” (Downs 2004). These tools are only a means to an end.

*Virtual Globes*

Digital or virtual globes are one type of geospatial technology increasingly used in classrooms. Their introduction has led to great interest in the spatial representation of data among many people with no expertise in geospatial technologies (Rakshit and Ogneva-Himmelberger 2008). Virtual globes combine a desktop application along with high-resolution imagery, digital aerial photography, and elevation data that streams from the Internet. The imagery for digital globes is a mosaic of images collected in recent years and is therefore not “real time.” The user may dynamically update data depending on the scale and geographic area selected. Users may contribute content that others may access in a virtual globe in several different formats. Vectors (points, lines, and polygons) may be created to identify locations of specified features, descriptive text and
photographs may be uploaded for each vector, image data layers may be uploaded onto the base imagery of the virtual globe, and 3D buildings may be uploaded from SketchUp, a free 3D modeling program. Some virtual globe products include Google Earth, ESRI’s ArcGlobe, NASA’s World Wind, Microsoft’s Bing Maps, KDE’s Marble, Skyline Globe, Wuhan University’s GeoGlobe, the Chinese Academy of Sciences Digital Earth Prototype System, and Unidata’s Integrated Data Viewer, and Digitnext’s VirtualGeo.

Table 2.2 illustrates the functionalities of six of the most well known virtual globes.

Table 2.2 Virtual Globes and Functionalities

<table>
<thead>
<tr>
<th></th>
<th>Google Earth</th>
<th>NASA World Wind</th>
<th>Bing Maps</th>
<th>Marble (KDE)</th>
<th>ESRI ArcGLOBE</th>
<th>SkylineGlobe</th>
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<tbody>
<tr>
<td>GPS Integration</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>Distance Measure</td>
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<tr>
<td>Drawing Tools</td>
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<tr>
<td>Movie Maker</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
<td>X^3</td>
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<tr>
<td>Street Map</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X^3</td>
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<tr>
<td>Satellite and Aerial Image</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>Weather Map</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X^2</td>
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<tr>
<td>Topographic Map</td>
<td>X^1</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Real-Time Traffic</td>
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</table>

X^1 - Can be added as a KML layer; X^2 - Shows real-time cloud images; X^3 - Pro version

A virtual globe is a 3D software model or representation of Earth or another world, which allows users to search and view satellite imagery and digital aerial photographs draped over a 3D representation of Earth as if they were flying above.

Virtual globes are restricted to represent 3D reality on common computer screens actually in two-dimensional (2D) visualization. Although they exist in a 2D environment, they
“provide a representation of 3D or sense of ‘3Dness’” (Elvidge and Tuttle 2008, 137). These globes fail at representing the original 3D globe in an adequate 3D form, because their underlying 3D data model always has to be mapped onto the 2D display. This transformation of the real, spherical shape of the world by plotting it onto a flat surface introduces the issue of distortion. Representing a three-dimensional sphere onto a two-dimensional plane simply cannot be achieved without distortion. In order to be able to notice optical depth on digital globes, it requires appropriate display devices, which allow 3D-perceptible visualization (Riedl 2007). The spatial image appears exclusively as a 3D illusion, thus still possessing distortion. For particularly large geographic areas, for instance, at the global-scale, maps all have some amount of distortion, and the type, amount, and location of distortion in different map projections can vary widely. Map projection affects the geometric properties of direction, distance, shape, and area. The challenge is to minimize these distortions or to preserve one particular geometric property. However, preserving one geometric property comes at the expense of distorting the remaining properties. While at this scale, distortion is not readily discernable, but it is still important to note.

“Unlike geographic information systems (GISs), which have a reputation for being difficult to learn, and force users to confront the intuitively difficult spatial concepts of scale and map projections, Digital Earth implementations such as Google Earth avoided projections entirely by showing the Earth as seen from space (technically a perspective orthographic projection onto the 2D plane of the screen), measured distance by using the length of the shortest path over the curved surface, and reduced scale to the simple metaphor of raising or lowering the user’s viewpoint” (Goodchild et al. 2012,
The representation on screen of a virtual globe is like a map. For example, a piece of string can be used on a real globe to measure the distance between two cities but cannot be used to measure that distance on a computer screen that shows a virtual globe. Rather the software function must be used instead. Therefore, distance is the most obvious distortion on a virtual globe with respect to its 2D display.

Another distortion is that digital globes typically display the earth as a sphere rather than a lumpy ellipsoid, its actual shape. A datum is a mathematical simplification of the shape of Earth, which defines how latitude, longitude, and elevation values are associated with particular points on the surface of the earth. For example, Google Earth uses the World Geodetic System of 1984 (WGS84). The way features and information are assigned locations on or near the Earth’s surface is called geo-referencing. Creating Google Earth features defines spatial positions of points using three values: latitude (x), longitude (y) and altitude (z). In order to transform the 3D Earth into a 2D map, some distortion of areas, distances, angles, and directions occur. Google Earth uses a cylindrical projection with a WGS84 datum for its imagery base. This projection, where the meridians and parallels are equidistant straight lines crossing at right angles, leads to distortion that increases away from the Equator. Information created using different projections may not be positioned correctly when added in Google Earth, which could cause even further distortion issues.

There are a number of advantages of using digital globes over printed paper maps. Quite simply, digital globes may be updated rather quickly while maps in print quickly become out of date. Perhaps two of the most notable advantages to educators in addition to the increased student achievement possibilities are the ubiquitous nature of
digital globe technology and freely downloadable applications that can be accessed through the Internet. Another advantage is the unlimited spatial navigation that the student is allowed to explore. Any part of the planet may be navigated and furthermore the student can change the scale at which locations are viewed. This option allows students to see more or less detail of a particular location depending on the scale at which it is viewed. In many areas of the world, a student can even inspect a location from the street view to ascertain architectural styles or land use of an area. In a sense, virtual globes offer a reality of an area to the student that a map does not. It simply makes locations come alive for students rather than just being a point, line, or polygon on a map. “There is no doubt that virtual globes had enormous advantages over traditional maps as a means of communicating data, information, and knowledge about the surface and near-surface of the planet” (Goodchild et al. 2012, 10089). While paper maps are portrayed at a fixed scale and typically offer high-resolution, large-scale information, digital maps are displayed at a lower resolution, but can be viewed at multiple scales and provide more dynamic, personalized and up-to-date content (Lloyd and Bunch 2003).

Virtual globes offer a different perspective that most students did not have access to prior to the availability of the application. For example, students may engage in looking at locations from non-north oriented views. Completing this same activity with a flat map, students may find it strange and difficult to accept the reality of the view. However, when done using a digital globe, the reaction is that of acceptance and “normalcy.” This simple activity arguably expands the way students think about locations spatially. Another activity would be to take a sightseeing tour using placemarkers and the fly-through functionality to examine the landscape of different regions. One example is
having students compare the dense human landscape of the northeast United States to the sparse human landscape of the southwestern United States. In crossing the country from east to west, many students may start to witness the terrain changes from region to region. These observations can lead to valuable discussions of the “whys of where.”

Another educational use that is beneficial in the classroom is the development of virtual fieldtrips (Green and Mouatt 2008; Krakowka 2012). By using the “add-on” utilities, teachers can add map and image overlays, links to texts and spreadsheet documents, and place 3D objects in a landscape.

The benefits of virtual globes, as with any technology, are “multiplied hundredfold in the hands of a teacher who can use the tool for inquiry-driven, active, problem-based, exploratory learning. Otherwise, students will likely be randomly flying around the Earth, learning about the location of places to be sure, but not engaging in the ‘whys of where’ that form the core of geographic inquiry” (Schultz, Kerski, and Patterson 2008, 32). Students have the ability to examine and interact with different landscapes and locales when being guided through the previously discussed virtual fieldtrips. “The ubiquitous nature of digital globe technologies provides significant opportunity for the science community to communicate information and share results of often complex models with people who traditionally could not operate or access spatial technologies such as GIS, remote sensing remote sensing and visualization products” (Aurambout, Pettit, and Lewis 2008, 509). Elvidge and Tuttle report that the number of people who are viewing, exploring and producing geospatial data with virtual globes is gone from thousands to millions and soon will be billions and thus vow that there are endless ideas for using virtual globes to conduct geospatial studies (2008).
Google Earth

The most popular virtual globe software is Google Earth, which possesses chief advantages such as speed, the most versatile user applications, and high-resolution satellite imagery over other virtual globe software (Schultz, Kerski, and Patterson 2008; Rakshit and Ogneva-Himmelberger 2008). It also has been presented as the most accurate and best performing of the virtual globes (Aurambout, Pettit, and Lewis 2008). Goodchild et al. (2012) asserts that Google Earth has even stimulated progress in communicating the results of science. The software is free but is closed-source meaning that users do not have the ability to modify the software to their specific needs. Google Earth not only allows the user to zoom into the data, pan around the data, rotate the view, and tilt the image to see 3D views, but also to overlay various themes such as roads, political boundaries, and topographic maps. The dynamic as opposed to static nature of digital maps is an important distinction, here. Tversky (2001) contends that useful maps are not simply reductions in the size of actual worlds, but useful maps extract the essential information and eliminate the inessential. Google has also enhanced the temporal dimensions of Google Earth, allowing the display of time series and the use of historic base maps.

Google Earth imagery is not viewed in real time, although data is continuously updated. The data come from a variety of sources and resolution is not uniform throughout the globe. Aerial photos and QuickBird satellite imagery (less than 1-m resolution) are used for some areas, Landsat imagery for other areas, and Shuttle Radar Topography Mission elevation is used for terrain imagery (10-m resolution for much of
the U.S.). The internal coordinate system is geographic coordinates (latitude/longitude) on the WGS84 datum.

The popularity of Google Earth has led to the development of a number of support websites allowing users to add their own geo-referenced map layers and images. Although primarily a visualization tool, Google Earth can function as a simplified, but highly limited, Geographical Information System (GIS) that “provides users with the capability to develop a customized geographical information system for any area, at any scale, for any part of the world” (Green and Mouatt 2008, 149). The nature of Google Earth allows students “to explore the earth in a dynamic and interactive manner, helping them understand the spatial context of their locale and engage in spatially-oriented learning in an entertaining and meaningful manner” (Patterson 2007, 146). However, research to date has only scratched the surface of the utility of Google Earth as an educational tool. GIS has dominated research on geospatial technology use in the classroom. Google Earth is not designed to replace professional GIS software, but it, along with other virtual globes, do provide an excellent introduction into geospatial technologies (Schultz, Kerski, and Patterson 2008). Furthermore, they assert that virtual globe software has the potential “to bring geographic inquiry to life – asking geographic questions, acquiring geographic resources, exploring geographic data, analyzing geographic information, and acting on geographic knowledge” (Schultz, Kerski, Patterson 2008, 30). Scholars also contend that Google Earth will only increase the amount of awareness of GIS’s potential uses, effectively prepare students to use more robust geospatial technologies, and potentially increase the ability to perform spatial
analysis (Baker 2005; Butler 2006; and Schultz, Kerski, and Patterson 2008; Green and Mouatt 2008; Kulo and Bodzin 2011).

2.6 BARRIERS TO CLASSROOM USE OF GEOSPATIAL TECHNOLOGIES

Multiple successes of geospatial technology integration into the classroom have been demonstrated through recent research (Shin 2006; Doering and Veletsianos 2007; Milson and Earle 2007; Allen 2007; DeMers and Vincent 2007; Campbell 2008; Liu and Zhu 2008; Kulo and Bodzin 2011). However, while geospatial technologies are at minimum stimulants for geographic awareness in the classroom, research discloses that there are multiple barriers that accompany their educational use (Kerski 2003 and 2008; Bednarz 2004; Kulo and Bodzin 2011). One of the immediate obstacles to classroom use is the lack of training and knowledge about geospatial technologies among K-12 teachers. This lack of knowledge most certainly translates into a lack of confidence to incorporate these tools in the classroom. In addition, there are few opportunities for pre-service and in-service teachers to participate in meaningful training where they have the chance to develop confidence in utilizing these technologies in the classroom, which ultimately leads to competence. Furthermore, even if a higher percentage of teachers did possess enough knowledge, and thus confidence, to implement these technologies, the era of standardized testing often prohibits teachers from allowing time into the curriculum for the inclusion.

Another possible barrier that can limit the use of geospatial technologies in the K-12 curriculum is the issue of lack of student focus while using these technologies. If students are utilizing technologies that exist on the Internet, a smartphone, or a tablet, there are many distractions that can lure them away from the task at hand. Students who
do know how to properly navigate the technology seldom stay on task and do not follow instructions. This situation not only limits the amount of learning taking place on the objectives of the lesson, but can also lead to other students in the classroom being tempted to lose focus as well. As an instructor, it can be difficult to manage and maintain group focus for any age group when it comes to technology.

Additionally, there are school-based and district-based issues that can create barriers for incorporation of geospatial technologies (Kerski 2003). Often times the most immediate hurdles are related to hardware, software, and networking issues that frequently occur. Recently, technologies have advanced in such a manner that many of them are free and have large amounts of easily accessible data. However, many schools or districts limit the amount of data that can be downloaded onto school computers, thus preventing use of these technologies in some areas. Moreover, a major issue in public schools is that teachers must compete for time in the computer lab so that each student or groups of two or three students may work on an individual computer. Often times, language arts teachers occupy the majority of this scheduled time leaving science and social studies teachers without an abundance of time to utilize the labs. In some cases there may be only one computer lab in the entire school building. This is not necessarily an educational issue with geospatial technologies themselves, but it does greatly limit access to the use of them outside of the entire class viewing it from the teacher’s monitor.

2.7 SUMMARY

A variety of literature has been reviewed here to set the background for why spatial thinking skills are rapidly becoming more important in the 21st century. Increasing interconnectedness in the modern world demands an unprecedented need for geographic
literacy. The ability to think spatially is crucial for making well-informed decisions. One way to teach spatial thinking skills is through geospatial technologies. Technology use has become ubiquitous in the classroom and the use of geospatial technologies is on the rise. The literature is inundated with the use of GIS in the classroom, but there is only a small body of literature about digital globes in the classroom. Furthermore, there is little empirical evidence that suggests technology instruction is better than traditional, paper instruction. This dissertation research fills a void in the literature by providing empirical evidence on the classroom use and effectiveness of digital globes versus paper maps.
CHAPTER 3

METHODS

The previous chapter investigated a literature review of geography education, learning, spatial thinking, spatial thinking assessments, geospatial technologies in the classroom, and barriers to using geospatial technologies in the classroom. This chapter describes the methods used in this study. Specifically, it provides details on the curriculum components, the study site and population, the research process, and data handling.

3.1 PREPARATIONS FOR THE STUDY

The Institutional Review Board (IRB) at the University of South Carolina certified this study in order to work with human subjects. To gain this certification, the researcher completed two learning modules and quizzes through the Collaborative Institutional Training Initiative (CITI): Human Research Curriculum and Social and Behavioral Responsible Conduct of Research Curriculum. Certification by the IRB was granted in January 2012.

This research was funded by a Doctoral Dissertation Research Improvement Grant, Geography and Spatial Sciences, Social, Behavioral, and Economics Sciences (SBE), National Science Foundation. The grant was awarded in June 2012 (Award # 1201873).
3.2 CURRICULUM COMPONENTS

In the State of South Carolina, the eighth grade social studies curriculum consists of the study of the state. Social Studies skills are taught and reinforced to aid in the student’s comprehension of the important role South Carolina plays in the history of the United States. This course is PASS-tested (South Carolina state assessment) and is based on South Carolina social studies standards, making this grade appropriate for the SC MAPS program. Google Earth was selected over other free digital globes available due to its familiarity and popularity among the general public. In this section, the two curriculum components utilized in the study as instructional media, SC MAPS and Google Earth, are described.

About SC MAPS

South Carolina Maps and Aerial Photographic Systems (SC MAPS) is a standards-based interdisciplinary middle school curriculum utilizing a diverse collection of aerial photographic and satellite images, maps, transparencies, and topographic maps. Originally designed in 1989, the curriculum has been updated several times to its most recent 4th edition in 2004 by its authors Dr. Peggy W. Cain of the South Carolina Department of Education, Dr. John R. Wagner of the Department of Geological Sciences at Clemson University, and James B. berry, III of the South Carolina Department of Natural Resources. This curriculum was funded by the ESEA, Title II Dwight D. Eisenhower Mathematics and Science Education Act, South Carolina Commission on Higher Education Cooperative Demonstration Grant Program, Harry Hampton Memorial Wildlife Fund, Duke Power Company Foundation, South Carolina University Research and Education Foundation, and the National Science Foundation.
The map products for this curriculum were carefully chosen to provide different spatial perspectives in a variety of map scales. The SC MAPS curriculum was designed to make connections between:

- Geologic events that have produced the state's five landform regions;
- Drainage systems, wetlands, and landform regions that have had an impact on the state's historical events, cultural diversity, and important wildlife habitats;
- Economic trends and regional differences that have resulted in land use diversity in relation to the state's industries, agriculture, and tourism;
- Historical events, regional customs, stories, and folk tales that have reflected the state's cultural diversity;
- Mathematical applications that have been used to solve problems involving concepts of fractions, decimals, percentages; principles of organizing data, graphic representation of numerical facts, and estimation.

The maps are utilized as a teaching tool by which students are given an opportunity to relate basic landform regions, historical development, and current land use patterns. Infrared photographs and topographic maps from the National High Altitude Photography Program (NHAP) and the United States Geological Survey (USGS) allow students to identify and explain a number of features in the state. For example, rapids visible on the Saluda and Broad Rivers made it easy to conceptualize that the Fall Line Zone was the dividing boundary between the Piedmont and the Coastal Plain regions of South Carolina. A closer inspection of the river systems and drainage patterns of the central part of South Carolina helped explain the distribution of early transportation routes, which resulted in Columbia being selected as the capital of the state. Furthermore,
General William T. Sherman's choice of cannon placement for bombardment of the State Capitol Building near the end of the Civil War made strategic sense when viewed on the aerial photograph.

The SC MAPS curriculum consists of imagery for 18 study sites across the 5 landform regions of the state. A state base map, a state soil and geologic map, and a land use/land cover map are also provided. An extensive teaching handbook, now in its fourth edition, is organized around higher-level thinking activities, a glossary, references, performance tasks, and enrichment activities.

The SC MAPS curriculum helps students develop basic science process skills such as observing, classifying, measuring, inferring, predicting, designing, and communicating – all skills that can be enhanced by spatial modes of thinking. The program also builds familiarity with the scientific method, including practice in formulating and testing hypotheses.

*About Google Earth*

Google Earth, a virtual globe software product launched by Google in 2005, was created by Keyhole Inc. and was initially called EarthViewer 3D. Acquired by Google in 2004, the software is based on Keyhole Markup Language (KML), an XML-based language originally developed by Keyhole Inc. Google Earth is a frequently updated computer application that provides opportunities to see Earth’s varied geography from scales that range from aerial to street-level views. Users have the ability to search and browse satellite imagery and digital aerial photographs which are draped over a three dimensional (3D) representation of the Earth. While existing in a two dimensional (2D) environment, it provides an incredibly realistic sense of 3D at certain scales. However,
when the user changes the scale by zooming in, a flattening of the image occurs taking away from this realistic sense of 3D. The Google Earth interface provides a basic set of navigational tools that resemble a dashboard display, which allow the user to zoom in and out, pan, rotate, and tilt the perspective of Earth as well as the ability to measure distances and view elevation levels. The application’s functionality is magnified by the ability to add layers of data and information to the 3D viewer such as place names, roads, boundaries, photographs, business names, current weather conditions, and 3D buildings to name a few.

Additionally, Google Earth allows users to create content within the application by inserting push-pins or pages with images, videos, or other links. Users may contribute content that others may access by creating vectors (points, lines, and polygons) that record locations of specified features and creating image data that can be viewed on top of the base imagery provided by Google Earth. Developed for use with Google Earth, these user contributions are made through Keyhole Markup Language (KML) files, a file format used for expressing geospatial data. Based on XML standard, KML uses a tag-based structure with nested elements and attributes.

The imagery from Google Earth is not “real-time”, but rather a mosaic of images collected from a variety of sources such as NASA, TerraMetrics, and Digital Globe. Google Earth can be considered a simple form of GIS because it allows the user to input, store, retrieve, display, and output both maps and images. Although simple, Google Earth provides a basic element of GIS functionality for navigation, retrieval and visualization. However, the lack of capacity for geospatial analysis of large amounts of data and the lack of access and control of the underlying data limits Google Earth as a true GIS (Green
and Mouatt 2008). Nonetheless, it has the potential to allow its users to understand geographic concepts such as location, scale, and place by analyzing remotely sensed data and information. Google Earth can be freely downloaded from http://earth.google.com. This website has a wide variety of instructional materials from tutorials to demonstrative videos.

3.3 STUDY SITE AND POPULATION

Study Site

This research was developed by a teacher in several local school districts around Columbia, South Carolina and thus has familiarity with these districts. One local school district, Lexington and Richland Counties School District Five, was identified to work with their Office of Accountability to fulfill the research authorization process in that district. A research proposal was submitted to that district in October 2012. The district approved the research request in February 2013 and assigned the study to one specific middle school within that district. Immediate contact was made with the principal of that school to set up a meeting to explain the project and to identify participating teachers.

The assigned school is located in Irmo, South Carolina, a town only 12 miles northwest of Columbia, South Carolina. The school has a total of 1,099 students (498 eighth grade students) and is composed of the seventh and eighth grades. The school is 50% male, 50% female, 29% free/reduced lunch, 59% Caucasian, 35% African American, 3% Asian, 1.5% Hispanic, and 0.6% American-Indian. The school received an absolute rating of “Excellent” on the South Carolina Annual School Report Card for 2012. Based on the result of PASS standardized tests, 17.7% scored below basic, 28.5% scored at the basic level, and 53.9% scored above basic.
Teacher Selection

To reduce teacher quality bias, two teachers were recruited to teach six classes of students each of the South Carolina course for a total of 12 classes included in the study. Each teacher would teach two different lessons: three using traditional paper instruction (SC MAPS) and three using digital instruction (Google Earth). There are four eighth grade social studies teachers at the middle school site, but due to time constraints with teacher schedules, school-wide testing schedules, and computer lab availability, only two out of the four teachers were selected to participate in the study. These two teachers were identified and selected by the school’s administration. The remaining two teachers did however administer the student survey and both the pre and post versions of the Spatial Thinking Abilities Test (STAT A and STAT B) to a total of six of their classes as a control group, but they did not teach the lessons to their students.

A survey was administered to the two participating teachers at the initial meeting with the researcher in March 2013 in order to obtain basic information about the teacher’s career in education and their comfort level in teaching with maps and technology in general. The document (Appendix A) consists of 13 questions. The first eight questions were free-response and were asked to establish educational background, geography training, length of time spent in the teaching profession and whether or not the teacher had previously used Google Earth in the classroom as a teaching tool. The last five questions asked the teacher to rank their comfort level on a scale from 1-5 (1 = not at all comfortable; 5 = extremely comfortable) in teaching with maps, using technology, teaching using technology, using Google Earth, and teaching using Google Earth.
Teacher 1, a white male in his eighteenth year of teaching, has a bachelor’s degree in Church Ministries and three Master’s degrees in Social Studies Education, Divinity, and Christian Education. He has never taught a stand-alone geography course in his career. Teacher 1 has taken a total of two geography courses in his educational history and has also received additional geography training by attending five Geofest workshops that are put on at the University of South Carolina by the South Carolina Geographic Alliance. Geofest is a full day professional development workshop for teachers. He has used Google Earth minimally in his classroom before for locational purposes only, but indicates he is not very comfortable using or teaching with Google Earth.

Teacher 2, a white male in his first year of teaching, has a bachelor’s degree in History and a Juris Doctorate. He has never taught a stand-alone geography course in his career. Teacher 2 has not taken any geography courses and has not used Google Earth in his classroom at all, but indicates he is extremely comfortable in using and teaching with Google Earth. Table 3.1 shows teacher responses about their comfort level in teaching with maps, technology, and Google Earth.

Table 3.1 Teacher Survey Responses on Comfort with Technology

<table>
<thead>
<tr>
<th>SURVEY CONTENT</th>
<th>TEACHER 1</th>
<th>TEACHER 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort with teaching using maps</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Comfort with using technology</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Comfort with teaching using technology</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Comfort with using Google Earth</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Comfort with teaching using Google Earth</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

1 = Not At All; 2 = Very Little; 3 = Somewhat; 4 = Very Much; 5 = Extremely

Participant Selection

The study is quasi-experimental meaning that a completely random student sample cannot be produced. Sampling is constrained by how the school assigns students
to their classes. Social Studies classrooms are assigned by ability level and are labeled as “College Preparatory” for students who have tested at a basic level in Social Studies or “Honors” for students who have tested at an above basic level in Social Studies. A decision was made to include all student classes from the selected teachers rather than just including the College Preparatory level students. By including the Honors level students, a larger data sample could be obtained which included all abilities and demographics.

Students who were enrolled in the Social Studies classes of the two selected teachers were chosen by default to participate in the study. Per district policy, parents and students in the selected teachers’ classrooms were first allowed to opt out of the study; the remaining student group participated in the study. An Informed Consent Form (Appendix B) was distributed to each student on March 15, 2013 upon which they were given two weeks to return the form and thus opt out of the study. The student/parent was instructed to return the form only if they chose to opt out of the study.

The design of the Informed Consent Form was largely district mandated. Parents of the students asked to participate in the research study and the students themselves are required to be notified about the study and to be informed about certain aspects of the study which include: the project’s purpose; how the student was selected; the procedure to be followed; anticipated benefits; possible physical, psychological, legal, or other risks; whether students will be personally identifiable and to whom; to whom the results will be available and for what purpose; participants’ or parents’ rights to inspect materials before consenting and to withdraw consent at any time; the person to whom inquiries should be addressed before, during, and after the project; that the school is neither
conducting or sponsoring the project; and the lack of adverse consequences of failure to participate.

In order to maintain a relatively equal sample of academic levels, the students in the control group were selected by academic level and scheduling day (A Day or B Day) from the other two teachers’ classes. One teacher administered the survey and tests to her Honors students on A Day while the other teacher administered the documents to her College Preparatory students on B Day.

Study Population

Three groups of students were required for the study, each consisting of 8th grade middle school students. The three groups included students participating in traditional paper instruction, students participating in digital instruction, and students participating in the control group without receiving any instruction. Each teacher taught a total of six Social Studies classes. Out of those six classes, each teacher taught three College Preparatory and three Honors classes. Each teacher taught three classes using SC MAPS instruction and three using Google Earth instruction. The two other eighth grade teachers who did not participate in teaching their students the lessons, administered the student survey, STAT A, and STAT B to three of each of their classes to create a control group. In total, the study engaged a total of 18 classes, six using traditional paper (SC MAPS) instruction, six using digital (Google Earth) instruction, and six with no intentional geography instruction. Each individual class contained a range of 13 to 26 students with an average of 21 students per class.

In total, 217 students were involved in the intervention group; 111 students were taught using the SC MAPS medium and 106 students were taught using the Google Earth
medium. There were 110 students involved in the control group. Teacher 1 taught a total of 122 students; Teacher 2 taught a total of 95 students. In order for there to be an equal amount of classes taught from each academic level and each medium, Teacher 1 taught two College Preparatory classes and one Honors class using the Google Earth medium while teaching one College Preparatory class and two Honors classes using the SC MAPS medium. Teacher 2 taught two Honors classes and one College Preparatory class using the Google Earth medium and one Honors class and two College Preparatory classes using the SC MAPS medium. Three College Preparatory classes and three Honors classes participated in the control group (Table 3.2).

Table 3.2 Number of Classes Taught by Academic Level and Condition

<table>
<thead>
<tr>
<th>TEACHER 1</th>
<th>TEACHER 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOGLE EARTH</td>
<td>SC MAPS</td>
</tr>
<tr>
<td>2 CP</td>
<td>1 CP</td>
</tr>
<tr>
<td>1 H</td>
<td>2 H</td>
</tr>
</tbody>
</table>

CP – College Preparatory; H – Honors

Out of 498 total eighth grade students enrolled in the school, 367 students were assigned to participate in the study. Data from 40 students was not usable as three students opted out of the study, two students were expelled from school during the study, and 35 students were absent for one or more of the administered activities bringing the total usable sample size to 327 students (Table 3.3). The study population was made up of 160 males, 167 females, 205 whites, 95 African-Americans, 22 Asians, 5 Hispanics, and 39 were identified as special education students based on the presence of an Individual Education Plan (IEP). There were 142 College Preparatory students and 185 Honors students involved in the study. This basic demographic information was obtained
by the teacher and was provided to the researcher without requiring individual student identification (name).

Table 3.3 Sample Size and Sample Percentage of Student Groups

<table>
<thead>
<tr>
<th>STUDENT GROUPS</th>
<th>SAMPLE SIZE *(n = 327)</th>
<th>SAMPLE PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC MAPS INTERVENTION</td>
<td>111</td>
<td>34.0%</td>
</tr>
<tr>
<td>GOOGLE EARTH INTERVENTION</td>
<td>106</td>
<td>32.4%</td>
</tr>
<tr>
<td>CONTROL</td>
<td>110</td>
<td>33.6%</td>
</tr>
<tr>
<td>MALE</td>
<td>160</td>
<td>49.0%</td>
</tr>
<tr>
<td>FEMALE</td>
<td>167</td>
<td>51.0%</td>
</tr>
<tr>
<td>WHITE</td>
<td>205</td>
<td>62.7%</td>
</tr>
<tr>
<td>BLACK</td>
<td>95</td>
<td>29.1%</td>
</tr>
<tr>
<td>ASIAN</td>
<td>22</td>
<td>6.7%</td>
</tr>
<tr>
<td>HISPANIC</td>
<td>5</td>
<td>0.1%</td>
</tr>
<tr>
<td>COLLEGE PREPARATORY</td>
<td>142</td>
<td>43.4%</td>
</tr>
<tr>
<td>HONORS</td>
<td>185</td>
<td>56.6%</td>
</tr>
<tr>
<td>SPECIAL EDUCATION</td>
<td>39</td>
<td>12.0%</td>
</tr>
</tbody>
</table>

3.4 RESEARCH PROCESS

_Spatial Thinking Ability Test (STAT)_

Serving as the spatial skills baseline prior to the SC MAPS/Google Earth intervention, each student completed the Spatial Thinking Ability Test (Lee and Bednarz 2012). This test was designed to assess an individual’s growth in spatial thinking skills. More specifically, it was created to assess the spatial thinking components identified in the structures and hierarchies proposed by Gersmehl and Gersmehl (2005) and Golledge _et al._ (2002).

The development of this spatial thinking test involved five steps: (1) identification of the test purpose and specification of concepts measured, (2) construction of the initial pool of items, (3) pilot testing, (4) item analysis, and (5) field testing (Lee and Bednarz 2009; Bednarz and Lee 2011; Lee and Bednarz 2012). The purpose of
developing this standardized test of spatial thinking abilities was to address the lack of and create a reliable and valid assessment instrument to measure the set of spatial thinking skills discussed in the previous works. Guidelines for developing test items were provided by Golledge and Stimson’s (1997) components of spatial relations.

The Spatial Thinking Abilities Test consisted of 16 multiple choice questions that assessed eight aspects of spatial thinking abilities including: (1) comprehending orientation and direction, (2) comparing map information to graphic information, (3) choosing the best location based on several spatial factors, (4) imagining a slope profile based on a topographic map, (5) correlating spatially distributed phenomena, (6) mentally visualizing 3D images based on 2D information, (7) overlaying or dissolving maps, and (8) comprehending geographic features represented as point, line, or polygon. Each test item was designed to measure one or two of these eight spatial thinking components.

In order to answer Questions 1 and 2, students should visually navigate road maps using verbal information including current location, directions to destination, and street information. These questions utilize “comprehending orientation and direction” (Golledge 2002). Answering Question 3, involves recognizing map patterns and representing them in graphic form. This question assesses “discerning spatial patterns” (Gersmehl 2005) and “graphing a spatial transition” (Gersmehl 2005). Answering Question 4 includes selecting an ideal location for a fictitious facility based on multiple pieces of spatial information such as land use, elevation, and population density. This question evaluates “comprehending overlay and dissolve” (Golledge 2002) and “inferring a spatial aura” (Gersmehl 2005). In Question 5, a profile of topography along a proposed line on a contour map should be created. Students need to properly orient themselves in
situ to answer the question. Several spatial thinking skills are utilized including “recognizing spatial form, being able to transform perceptions, representations and images from one dimension to another and reverse” (Golledge 2002) and “graphing a spatial transition” (Gersmehl 2005). In order to answer Question 6, students should identify spatial correlations between sets of maps. Additionally, in Question 7, students should display the identified spatial relationship in graphic form. These questions assess “comprehending spatial association” (Golledge 2002), “making a spatial comparison and assessing a spatial association” (Gersmehl 2005). Moreover, Question 7 assesses “graphing a spatial transition” (Gersmehl 2005). Answering Question 8 requires students to mentally visualize a 3D image based on 2D information. It evaluates “being able to transform perceptions, representations and images from one dimension to another and the reverse” (Golledge 2002). Questions 9, 10, 11, and 12 all necessitate students to visually verify a map overlay process and then select the appropriate map layers involved in the overlay. These questions evaluate “overlaying and dissolving maps” (Golledge 2002). Finally, Questions 13, 14, 15, and 16 involve students visually extracting types of spatial data from verbally expressed spatial information. These questions measure “comprehending integration of geographic features represented as points, networks, and regions” (Golledge 2002) and “comprehending spatial shapes and patterns” (Golledge 2002).

A primary focus during the development of the test was how to “ensure practicability while at the same time providing maximum comprehensibility of spatial thinking concepts” (Lee and Bednarz 2012). Other factors considered in the design of the test included “(1) cognitive process (i.e., maximizing spatial processes and minimizing
verbal processes); (2) psychometric rationale; (3) mode of representation (text, picture, graph, map, color versus black and white, etc.); and (4) practical constraints (e.g., amount of time required to complete the test)” (Lee and Bednarz 2012).

A pilot test was completed using 86 subjects (49 females and 37 females) from a large state university. Item analysis was conducted for each question and items that were too difficult, too easy, or unclear were eliminated or revised. Several additional pilot tests were completed after revisions were made. Reliability and construct analysis of the test was examined with test results from 352 students from four different universities, one high school, and one middle school.

Two equivalent forms of the test, STAT A (Appendix C) and STAT B (Appendix D), were created with slightly different questions covering the same spatial thinking skills so that it may be administered as a pre- and post-test to evaluate changes in spatial thinking skills over a period of time. STAT B is a variation of STAT A where answers to questions have been rearranged or a slightly different angle on a map is used. Both STAT A and STAT B were used in their entirety as a baseline for this study.

Curriculum Modification and Design

SC MAPS and Google Earth, as interactive teaching formats, can foster a rich student learning environment as students are immersed in project based learning (learning by doing) (Bednarz 2000; Baker and White 2003; King 2008; Liu and Laxman 2009; Liu et al. 2010; Demirci et al. 2011). Rather than listening to a discussion of soil types and their relationship to crop location, a student may interactively engage the same data for further inquiry. Factual retention, problem solving skills, and critical thinking are improved (Gallagher, Stepien, and Rosenthal 1992; Camp 1996; and Shepherd 1998).
Two curriculum components are needed for this study: 1) the original, existing SC MAPS curriculum; and 2) an updated SC MAPS curriculum that integrates Google Earth without SC MAPS materials. The current SC MAPS materials are available for review at: http://artsandsciences.sc.edu/cege/resources/scmaps/scmaps.html.

Original SC MAPS Activity

The example cited here represents a small fraction of the SC MAPS curriculum already developed. The Charleston, South Carolina area study site (Figure 3.1) illustrates the concept. One current activity has the student estimate roof damage to Charleston from hurricanes.

“In 1989, Hurricane Hugo swept through the city of Charleston causing roof damage to about 80% of all buildings. Use the CHARLESTON LITHOGRAPH (aerial imagery) to estimate the total number of buildings in Charleston that had to be re-roofed after Hurricane Hugo. Limit your estimate to the buildings located south of Interstate Hwy. 26 and US Hwy. 17 all the way to the Battery. Use the transparent grid overlay to determine the number of buildings per square grid inch. Then set up a proportion to estimate the total number of buildings in the designated area. Compare your answer with answers of other groups. Why does each group get slightly different answers? Can they all be correct?” (SC MAPS 2004, 9A-10).

This activity supports the development of the following skills: region (identifying differing damage zones), transition (abrupt v. gradual change in damage), pattern (evenly spaced damages or clusters), and association (damages and building type).
The existing curriculum is heavily designed with student activities that use both topographic maps and infrared imagery. In order to be able to teach lessons to students using both instructional media equally, the existing curriculum had to be modified without the use of topographic maps and infrared imagery, which was replaced with non-infrared satellite imagery. Moreover, the questions in the existing curriculum had to be redesigned without questions utilizing the previously mentioned tools. Two existing study sites, Charleston and Myrtle Beach, were selected and re-designed for this research. The study sites were drawn outside the Columbia, South Carolina area to eliminate local familiarity by the students.

No prior technical knowledge of aerial photography or satellite imagery is required as most students will have taken photographs themselves and will understand the basic principles of photography. “The relationship of camera altitude to scale is important and can be related to students’ perceptions of image size on a photograph diminishing
with the object’s distance from the camera. Although satellite images are not technically photographs, the imaging process produces which can be treated as pictures without loss of significance” (SC MAPS 2004, 39). A major advantage to satellite imagery is that large areas can be scanned at one time so that the “big picture” may be seen. However, the existing satellite images in the SC MAPS curriculum uses images that are at too small of a scale to be used effectively for the purposes of these lessons. Images acquired from high altitude aircraft or satellites are valuable sources of information to study Earth’s landforms, geology, vegetation, and land uses; however, this existing infrared imagery is not comparable to the satellite imagery from Google Earth. Newer imagery was needed for comparable SC MAPS versus Google Earth activities. These images of the Charleston and Myrtle Beach study sites were acquired from Bing Maps, (http://www.bing.com/maps) printed, and laminated for classroom use (Figures 3.2 and 3.3). The exact imagery was captured and framed, as described below, in a polygon on Google Earth so that the students in both instructional media groups were viewing the same designated area of size (Figures 3.4 and 3.5).
Figure 3.2 Bing Maps, Charleston Study Site
Figure 3.3 Bing Maps, Myrtle Beach Site

Figure 3.4 Google Earth, Charleston Study Site
In order for students to identify points (i.e. Point A, Point B) and areas mentioned in the activities on the printed satellite imagery maps, bright orange ½ inch, round stickers were used so that they may be removed or changed for future use of the printed imagery. In order for the students being instructed via Google Earth to identify these points and areas, polygons were created in ESRI’s ArcMap as a graphic, then converted to a shapefile, and exported as a kmz file, which then had to be uncompressed. The points were located directly in Google Earth and were saved as a kml file. The two kml files were then merged together and loaded onto the computers in the lab that students used in this study.

The student activities were designed to isolate specific spatial thinking skills as possible/appropriate. Each of the two lessons (Appendices E and F) contained five spatial thinking activities that students answered by using their assigned instructional media,
paper or digital. Each lesson also contained a short set of introductory readings about the study site area and instructions for basic map reading skills, which students read as a class before completing the activities. The activities were designed to pair multiple spatial thinking skills to the existing and modified curricula and assess their use via the different learning strategies. Each activity was designed to measure one or two spatial thinking skills.

The Charleston study site, Lesson 1, began by identifying and comprehending geographic features in Activity 1 by asking students to decide whether features were represented by points, lines, or areas and using the directional indicator to decipher the direction of travel from one point to another. Activity 2 requires students to use location and comparison by asking them to locate a particular feature and then compare it to another feature. The activity also asked students to identify clues in the map that helped them reach their answer. In Activity 3, the students again use comparison as they decide which of two areas is a more industrialized area. They are again asked to identify clues in the map that helped the reach their answer. Furthermore, they are asked to utilize aura, describing the influence that a place can have on neighboring locations, to explain why industry is located in a particular place. Activity 4 requires students to decide whether two identified points are developed or undeveloped and why they chose their answer. It goes on to necessitate comparison, transition and association as students are asked to identify and explain whether the land between the two points changes abruptly or gradually. Lesson 1 concludes with Activity 5, which asks students to again utilize aura as they are provided with a hypothetical situation in which they must decide the more
appropriate of two proposed routes to establish a water ferry. They are then asked to explain their answer.

The Myrtle Beach study site, Lesson 2, begins by asking students in Activity 1 to locate a feature, measure the distance between two points and use the directional indicator to decipher the direction of travel from one point to another. Activity 2 employs transition as it requires students to locate a feature, draw a line equaling a certain distance, and decide whether the change in water color is gradual or abrupt. Students are then asked to explain the reasoning behind the changing water color. Activity 3 utilizes aura as it asks students to identify the major orientation of an identified feature and then asks them to explain why that feature is oriented in that way as opposed to another orientation. In Activity 4, students were asked to mentally visualize 3D images based on 2D information by deciding which direction they would be traveling if they properly oriented themselves in situ and traveled towards a designated point. Finally, in Activity 5, students utilize aura as they are given several spatial criteria to determine the best location for a new cell tower. Based upon those identified criteria, they must decide the best location of the new cell tower between several points on the map. They are then asked to explain their choice and why the other three sites were unacceptable.

Pilot Testing of Student Activities

Prior to implementation in the classroom, a pilot test of the classroom lessons that were designed for the study was held in April 2013. The primary motive behind the pilot test was to verify grade-level appropriateness and identify flaws in design of the classroom activities. This session was devoted to explaining the project aims and concepts and teacher feedback was used in finalizing the curriculum development.
process. Each activity was tested by four middle school, social studies teachers. Two were student teachers from the University of South Carolina, while the other two were the teachers used in the study. The teachers worked through all activities in both the SC MAPS and the Google Earth curriculum components for both the Charleston and Myrtle Beach study sites. The average time to complete each lesson was 20-25 minutes. All of the activities were found to be grade-level appropriate and intellectually engaging. Three teachers preferred using the SC MAPS component to complete the lessons, while the fourth teacher preferred using the Google Earth component.

After the lessons had been pilot tested with the teachers, the procedures of the entire study were tested using an eighth grade honors student who did not later participate in the study. Had this individual not been an honors student, some of the difficulties that students encountered might have been better anticipated. This student completed the survey, STAT A, Lesson 1, Lesson 2, and STAT B to determine clarity and gauge the time needed for the completion of each activity.

Teacher Preparation

An initial meeting was held with the teachers and the media specialist on March 14, 2013 to provide them with an overview of the study and to schedule all of the dates for implementing the study. The teachers reviewed the Informed Consent Form and were provided copies to send home to parents of their students. Next, the teachers reviewed the Student Survey and were asked for their input on its contents. Teacher 1 suggested that there be a question assessing the amount of access to computers students had outside of school. Teachers were also instructed how to fill out basic demographic data on each
student at the bottom of the student survey so that the researcher would not be exposed to student names and students would not have to answer demographic questions.

Finally, the teachers were provided with a sample of the STAT questions so they were able to gain some insight of the types of questions their students would be asked to answer. The teachers also completed the aforementioned teacher survey (Appendix A).

Two training sessions were held on April 22 and 24, 2013 for the two teachers piloting the new curriculum. In these sessions teachers were made aware of the SC MAPS program and Google Earth software (some familiarity is already expected for Google Earth based on responses to survey questions.). The curriculum modules were demonstrated and any outstanding issues were clarified prior to implementation of the lessons. Teachers were also provided with a set of step-by-step written instructions for each lesson with correct answers to maintain equality during instruction and to use as a guide during instruction (Appendix G).

**Student Survey Construction**

Before engaging SC MAPS or Google Earth modules, students completed a basic questionnaire and attitudinal survey. To maintain confidentiality, a cover sheet was attached to the survey where the student could write their name. Beside the space for the student to write their name was a pre-coded student number. The teacher removed this cover sheet after collecting the completed survey to keep for their records. This same number would be assigned to a student for the remainder of the study. Each survey was pre-coded at the bottom of the page with the same student number on the cover sheet that identified the student with their assigned teacher, the section in which the student was enrolled, the academic level of his/her class, and the specific number assigned to that
particular student. A code may have been R3BH17, for instance. This indicated that the response was from Mr. R’s (R) third block “B-Day” (3B) Honors (H) class. The number 17 is the individual student identifier in that particular class.

After this number were several letters followed by blanks for teachers to fill in demographic data about that student so that the researcher was not exposed to student names. The letters G, R, L and SE signaled the teacher to report the gender, race/ethnicity, academic level (College Preparatory or Honors), and special education status (yes or no) of the student. Special education status was represented by the presence of an Individual Education Plan (IEP). This method of providing demographic information also shielded the student from reporting this information to researchers.

The student survey is divided into two parts and consists of 14 total items (Appendix H). The first part of the instrument included 10 items and was measured on a 5-point Likert-type scale, which was rated by the students from 1 (strongly disagree) to 5 (strongly agree). These items were used to gather basic information on student attitudes on learning about geographic content, working with computers, and using maps and as well as their ease in doing so. It also gathered information on student access to computers and the Internet outside of school. Containing four items, the second part was designed to gather information about the students’ travel experiences and the travel experiences of their parents, a possible influence on their spatial understanding. This part of the instrument required a response of yes, no, or don’t know.

The design of the survey followed the 5-point Likert-type scale used in both surveys reviewed from research literature on student attitudes about geography (Walker 2006 and Kubiatko et al. 2012). Both of these studies suggest that attitudes toward
geography may be linked to performance, thus these types of questions were developed in the survey for this study. More specifically, the items were adapted and modeled after the popular Test of Geography-Related Attitudes (ToGRA) (Walker 2006) whose survey was designed to evaluate student attitudes on four scales, leisure interest in geography, enjoyment of geographic education, career interest in geography, and interest in place. This instrument contained 29 items and in an attempt to obtain reliability, was extremely repetitive. A decision was made to develop a shorter, less repetitive instrument while maintaining the four scales that were used in the original instrument. Four items from ToGRA were used verbatim: I enjoy looking at maps and globes; I enjoy learning (studying) about people and places; A job that uses maps would be exciting; and I would like to study geography in college to help me get a job. The word “geography” was intentionally not used in the items assessing student attitudes on geographic content because these students are not enrolled in a geography course at the middle level and thus may not be able to correctly decipher what material constitutes as geographic. In addition to the question used from ToGRA on whether or not students enjoy learning about people and places, which focuses on the human perspective of geography, an item was added of the same nature about the environment to assess student enjoyment of the physical perspective of geography. Also expanding from an existing question, an item was added to assess the comfort in which a student uses maps and globes. Furthermore, items to assess student enjoyment, ease, and access to computer technology were also included.

Administration of Student Survey and STAT A

Data collection was obtained from participating students in April and May of 2013. Students were informed that the survey and STAT A were both anonymous and
non-graded assessments. Students were also informed that no information identifying individual students would be collected and all data would be kept confidential. On April 11 and 12, 2013, exactly one month prior to implementation of the modules, the students took the survey and STAT A. The STAT was administered on paper in black and white rather than in color. After STAT A was conducted, no feedback was provided to the students concerning their performance.

Implementation of Student Intervention Lessons

Scheduling available time with the school to avoid End-of-Course testing and state standardized testing was imperative. Next, scheduling available time to conduct the lessons was influenced by classroom time available for both teachers as well as computer lab availability. Lesson 1 was taught on May 13 and 14 and Lesson 2 was taught on May 15 and 16, 2013. In order for lessons to be administered to students on consecutive days in their class, there were two days of Lesson 1 implementation followed by two days of Lesson 2 implementation. The lessons were taught in this way because of the school’s A/B block schedule where every other day is scheduled as an “A Day” and to alternate "ABABA" weeks with "BABAB" weeks. Each student attends a particular class every other day for the duration of the school year.

Administration of STAT B

On May 21 and 22, 2013, the class period immediately following the lesson interventions, students completed STAT B and differences between the various groups were investigated. Performance on STAT A and STAT B was based on the number of questions answered correctly. Quantitative data was analyzed using SPSS®. Students were not given any feedback concerning their performance after completing STAT B,
however, teachers were issued the answer key and discussed correct answers and the reasoning for each answer to provide some feedback to the students after the study was completed.

*Student and Teacher De-brief*

There is more to be gained from this study than quantitative data alone. In an effort to collect qualitative data, a subset of students representing different outcomes on the STAT, were invited to share their opinions about the activities in order to develop a richer understanding of their experiences. A random number generator was used to select two students out of each of the twelve intervention classes. The generator provided extra random numbers in the event that the student with the selected number was absent. A total of 24 students were interviewed about their experiences of the activities in the study. Immediately after completing STAT B these students were asked to answer the following questions:

a) What was the easiest question(s) on the pretest? What was easy about this question? What strategies did you use?

b) What was the most difficult question(s) on the pretest? What was difficult about this question? What strategies did you use?

c) Did exposure to the STAT A questions help you in the activities?

d) Describe your level of interest in the types of activities we did on Charleston and Myrtle Beach.

e) Describe the level of difficulty or ease you had in answering the questions in the activities.
f) Which tools did you use the most in answering the questions? (zoom, ruler, compass) Students using Google Earth were asked if they used tools such as the “roads layer” even though they were asked not to. Students using SC MAPS were asked if they ever turned the map to orient themselves to help answer a question.

g) Do you feel that you learned how to read and use maps better after completing these activities? Do you think the activities helped you do any better on STAT B?

h) What do you think you learned from completing these activities?

The two teachers who taught the intervention lessons were also interviewed and asked to comment on:

a) Their level of satisfaction with the intervention lessons, as well as, the perceived student level of satisfaction

b) How well the SC MAPS intervention lessons aligned well with the relevant South Carolina educational standards

c) The levels of interest and curiosity among students and teachers in spatial concepts

d) The levels of interest and curiosity among students and teachers in using and understanding technology relative to the subject matter

e) The most positive, negative, interesting, or surprising comments or questions heard from students during the completion of the lessons

f) The most challenging aspect of teaching with SC MAPS

g) The most challenging aspect of teaching with Google Earth
h) The value of the lessons for improving spatial thinking (in what ways does it improve spatial thinking, especially as it relates to differences in delivery – paper v. digital?)

i) Their preferred medium and why, as well as, the perceived preferred media of the students

j) The medium that seemed to better improve student spatial thinking

These conversations were recorded, transcribed, and evaluated for common themes.

3.5 DATA HANDLING

By mid-May 2013 the STAT B and the post student and teacher interviews had been administered and collected. A template was then created in the data management system, *File Maker Pro*. This database software was chosen over *Microsoft Access* and *Google Docs* because it is off of the cloud and user-friendly. The researcher entered data from the documents of each usable student.

3.6 CHAPTER SUMMARY

This chapter has described the methods used in this study. Specifically, it provided details on the curriculum components utilized in the study, the study site and population, the research process, and the processes used for data handling. The following chapter explores the quantitative findings from this study by examining student responses to the STAT and to the student survey.
CHAPTER 4

ANALYSIS OF THE DIFFERENCES IN STAT SCORES AMONG STUDENTS

This research is ultimately about the influence of different media, among other variables, on student spatial thinking skill acquisition. The first research question addressed in this chapter specifically investigates whether spatial thinking skill development differs between analog (paper) and digital map instructional delivery. The expectation that students who receive instructional intervention will indeed perform better than students who did not, is not without merit. It is further anticipated that students who receive paper map instruction will perform better than those who receive digital map instruction based on the research of Meyer et al. (1999); Verdi et al. (2003); Cunningham (2005); Pederson, Farrell, and McPhee (2005); and Hurst and Clough (2013). This expected result is also supported by the classroom experiences of the researcher, a veteran K-12 geography teacher. The following three sections discuss the findings from the differences in STAT scores among students. The analysis progresses through an investigation of STAT scores analyzed by condition, STAT question, and spatial thinking skill area. Finally, the relationship between student survey responses and STAT score improvement is explored.

Many variables may contribute to how a student best learns spatial thinking skills. The second research question addressed in this chapter investigates whether variables beyond different media have a role in spatial thinking skill development. Additional
variables such as attitudes towards geography and technology, access to technology, past travel experience, and demographic variables such as gender, race, academic level, and special education status are explored. It is anticipated that the more favorable the attitudes towards geography and the more past travel experience a student has, the better they will perform on spatial thinking skill assessment. It is also expected that males will perform better than females. The analysis progresses through an examination of each of these variables by condition. Also examined are possible interaction effects among the demographic variables related to the different instructional media.

4.1 FINDINGS FROM STAT SCORES ANALYZED BY CONDITION

All three student groups in the study participated in both the pre-test, STAT A, and the post-test, STAT B. The scores for each of the three groups: control, Google Earth, and SC MAPS were tested and analyzed for significant differences. For all analyses, the confidence level was set at 95%.

Comparing STAT A across Conditions

An analysis of variance (ANOVA) was performed as a baseline to test for statistically significant differences between the treatment groups before the intervention occurred. The overall findings were significantly different, \( F(2, 324) = 3.499, p = .031 \) in a 2-tailed ANOVA. A Post-Hoc Multiple Comparisons t-test (LSD) was performed using independent samples because the same student does not have a matching score in each group (Table 4.1). The results showed that, on average, the students segmented into the control group scored higher than the students who would receive the Google Earth intervention.
Table 4.1 Multiple Comparisons t-test between Conditions in STAT A

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean</th>
<th>Difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT A Overall</td>
<td>.400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>.434</td>
<td>Control – Google Earth</td>
<td>.009*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control – SC MAPS</td>
<td>.156</td>
</tr>
<tr>
<td>Google Earth</td>
<td>.368</td>
<td>Google Earth – Control</td>
<td>.009*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Google Earth – SC MAPS</td>
<td>.216</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>.399</td>
<td>SC MAPS – Control</td>
<td>.156</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC MAPS – Google Earth</td>
<td>.216</td>
</tr>
</tbody>
</table>

Significant * p ≤ .05

Comparing STAT B across Conditions

An analysis of variance (ANOVA) was also conducted treating STAT B as dependent upon the three conditions of instructional delivery. The overall findings were that there was no significant difference of scores by condition, F(2, 324) = 1.894, p = .152. This result is puzzling in that there was a statistical difference in STAT A, but there was no statistical difference in STAT B, which took place after students received instructional intervention. These results indicate that because the students in the control group improved slightly more than the students in the Google Earth group in STAT A, then the students in the Google Earth group had a larger improvement in STAT B, because there was no statistically significant difference between groups in that test. This could signify that the lesson interventions aided in the improvements by the students in the Google Earth group.

Overall Scores from STAT A to STAT B

Paired t-tests were conducted to compare changes in performance through time from STAT A to STAT B across different conditions in the total study population. First, a paired t-test was used to determine if there was an overall difference in the average percentage of correct answers between STAT A and STAT B. This test included the
entire study sample (n = 327). A one-tailed test was performed here in order to identify statistically significant increases within the means of each group. The results indicated that there was a highly significant improvement on correct answer percentage scores from STAT A to STAT B, \( t(326) = -5.938, p = .001 \) (Table 4.2).

**Control Group Scores from STAT A to STAT B**

A paired t-test was also run for each of the three conditions: control, Google Earth, and SC MAPS to determine if there was an overall difference in the average percentage of correct answers between STAT A and STAT B. The results indicated that there was not a statistically significant difference in scores from STAT A to STAT B in the control (n = 110) group, \( t(109) = -1.036, p = .302 \) (Table 4.2). This result was expected because there was no instructional intervention conducted in this group between the administration of STAT A and STAT B.

**Intervention Group Scores from STAT A to STAT B**

The Google Earth (n = 106) and the SC MAPS (n = 111) intervention groups both showed highly statistically significant differences in the average percentage of correct answers between STAT A and STAT B (Table 4.2). The Google Earth intervention group showed highly statistically significant differences, \( t(105) = -3.695, p < .001 \). The SC MAPS intervention group showed highly statistically significant differences, \( t(110) = -5.635, p < .001 \). Once again, a one-tailed test was conducted in order to identify significant improvements in test scores. Although there was a highly significant improvement in both instructional intervention groups, the measurable improvement is more in the SC MAPS group than in the Google Earth group. In Google
Earth, the mean test score improved by approximately 5.9%, while in SC MAPS the mean test score improved by approximately 8.1%.

Table 4.2 Paired t-test – Percent Correct from STAT A to STAT B by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>-5.938</td>
<td>.001*</td>
</tr>
<tr>
<td>Control</td>
<td>-1.036</td>
<td>.302</td>
</tr>
<tr>
<td>Google Earth</td>
<td>-3.695</td>
<td>P &lt; .001*</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>-5.635</td>
<td>P &lt; .001*</td>
</tr>
</tbody>
</table>

Significant * p ≤ .05

4.2 FINDINGS FROM STAT SCORES ANALYZED BY QUESTION

Overall Percent Correct by STAT Question

The overall correct answer percentages from the total study population for each question in both STAT A and STAT B are shown in Figure 4.1. Several noteworthy observations can be made upon viewing these figures. There are 16 questions on each of the equivalent versions of the STAT. Students improved their scores from STAT A to STAT B on 12 questions, thus improving their scores on 75.0% of the questions. The scores for Question 16 (Comprehending Geographic Features) did not decrease or increase. Students fared worse on STAT B on Questions 2, 3, and 6.

Out of the total study population, the question that students scored the highest on and the question that students scored the lowest on were the same in both versions of the STAT. Students scored the highest on Question 3 (Comparing Map Information to Graphic Information) and the lowest on Question 12 (Overlay and Dissolve) in both STAT A and B. Question 4 (Choosing Best Location) saw the most improvement in this group, increasing by 17.2%, while Question 11 (Overlay and Dissolve) saw the least improvement, increasing by 1.9%. Question 3 (Comparing Map Information to Graphic
Information) had the smallest fluctuation of change with students performing slightly better in STAT A than in STAT B by 1.2%.

![Overall Percent Correct by STAT Question](image)

**Figure 4.1 Overall Percent Correct by STAT Question**

**Control Group Percent Correct by STAT Question**

The correct answer percentages for each question in both STAT A and STAT B for the control group are shown in Figure 4.2. These figures reveal some interesting observations about particular questions. Students improved their scores from STAT A to STAT B on 12 out of 16 questions. In essence, students improved their scores on 75% of the questions even though they were not exposed to the instructional interventions. In the control group, students fared worse on STAT B on Questions 2 (Orientation and Direction), 3 (Comparing Map Information to Graphic Information), 6 (Correlating Spatially Distributed Phenomena), and 11 (Overlay and Dissolve). With the exception of Question 11, these are the same questions that decreased in correct percentage in the overall category.
The question that students scored the highest on was Question 6 (Correlating Spatially Distributed Phenomena) in STAT A and Question 3 (Comparing Map Information to Graphic Information) in STAT B. Although students scored highest on Question 6 in STAT A, Question 3 was a close second scoring only 0.02% behind Question 6. Students scored the lowest on Question 12 (Overlay and Dissolve) in both STAT A and B. This observation is again similar to the findings of the overall scores. Question 4 (Choosing Best Location) saw the most improvement in this group, increasing by 13.6%, while Question 7 (Correlating Spatially Distributed Phenomena) saw the least improvement, increasing by only 0.3%. The question that showed the most difference in versions of the STAT was Question 6 (Correlating Spatially Distributed Phenomena), decreasing by 14.7% from STAT A to STAT B.

![Control Group Percent Correct](image)

Figure 4.2 Control Group Percent Correct by STAT Question
Google Earth Group Percent Correct by STAT Question

The correct answer percentages for each question in both STAT A and STAT B for the Google Earth group are shown in Figure 4.3. These percentages disclose some interesting findings about particular questions. Students improved their scores from STAT A to STAT B on 13 out of 16 questions, thus improving their scores on 81.3% of the questions. Students fared worse on STAT B on Questions 6 (Correlating Spatially Distributed Phenomena), 11 (Overlay and Dissolve), and 16 (Comprehending Geographic Features). Again, there is a commonality with the control group among declining scores on Questions 6 and 11 in STAT B.

The question that students scored the highest on was Question 3 (Comparing Map Information to Graphic Information) in both versions of the STAT. Students scored the lowest on Question 12 (Overlay and Dissolve) in STAT A, while scoring lowest on Question 8 (Mentally Visualizing 3D Images) in STAT B. Question 8 only fared worse than Question 12 by 0.02% in STAT B. Again, Question 12 remains the lowest scoring item among most students. Question 15 (Comprehending Geographic Features) saw the most improvement in this group, increasing by 22.5%, while Question 8 saw the least improvement, increasing by only 0.6%. Overall in the Google Earth group there was higher range of scores between the two versions of the STAT than there was in the control group.
The correct answer percentages for each question in both STAT A and STAT B for the SC MAPS group are shown in Figure 4.4. Some interesting observations about particular questions can be made upon viewing these percentages. Students improved their scores from STAT A to STAT B on 14 out of 16 questions, thus improving their scores on 88% of the questions. Students in this group improved more than any other group based on percentage of questions answered correctly. Students faired worse on Questions 2 (Orientation and Direction) and 3 (Comparing Map Information to Graphic Information). Again, there is a commonality with the control group among declining on Questions 2 and 3 in both versions of the STAT.

The question that students scored the highest on and the question that students scored the lowest on were the same in both versions of the STAT. Students scored the highest on Question 3 (Comparing Map Information to Graphic Information) and the
lowest on Question 12 (Overlay and Dissolve) in both versions of the STAT. Again, Questions 3 and 12 remain the highest and lowest scoring item, respectively among most students. Question 4 (Choosing Best Location) saw the most improvement in this group, increasing by 18%, while Question 16 (Comprehending Geographic Features) saw the least improvement, increasing by 0.06%.

4.3 FINDINGS FROM STAT SCORES ANALYZED BY SPATIAL THINKING SKILL AREA

There are 16 questions on each of the equivalent versions of the STAT. Each question tests one or two of the spatial thinking skills identified by Golledge et al. (2002) and/or Gersmehl and Gersmehl (2005). According to the authors, Bednarz and Lee (2012), there are a total of 8 aspects of spatial thinking abilities identified and tested in the STAT. Each of the 16 questions was divided, by its authors, into these 8 categories of spatial thinking skills shown in Table 4.3.
Table 4.3 Spatial Thinking Skill Categories by Question

<table>
<thead>
<tr>
<th>Type</th>
<th>Spatial Thinking Skill(s)</th>
<th>STAT Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Comprehending Orientation &amp; Direction</td>
<td>1, 2</td>
</tr>
<tr>
<td>II</td>
<td>Comparing Map Information to Graphic Information</td>
<td>3</td>
</tr>
<tr>
<td>III</td>
<td>Choosing Best Location Based on Several Spatial Factors</td>
<td>4</td>
</tr>
<tr>
<td>IV</td>
<td>Imagining a Slope Profile Based on a Topographic Map</td>
<td>5</td>
</tr>
<tr>
<td>V</td>
<td>Correlating Spatially Distributed Phenomena</td>
<td>6, 7</td>
</tr>
<tr>
<td>VI</td>
<td>Mentally Visualizing 3D Images Based on 2D Information</td>
<td>8</td>
</tr>
<tr>
<td>VII</td>
<td>Overlaying and Dissolving Maps</td>
<td>9, 10, 11, 12</td>
</tr>
<tr>
<td>VIII</td>
<td>Comprehending Geographic Features Represented as Point, Line, or Polygon</td>
<td>13, 14, 15, 16</td>
</tr>
</tbody>
</table>

Frequency Table Data for the Spatial Thinking Skill Areas

A frequency table was run for the total population and all three conditions: control group, Google Earth group, and SC MAPS group in order to evaluate change in scores in each of the eight skill areas. The condition was the independent variable, while the difference in the percentage of correct answers in a skill area (STAT B – STAT A) was the dependent variable. Three percentages were presented: decrease in score, no change in score, and increase in score (Table 4.4).
Table 4.4 Frequency Table for Score Change in Skill Area by Condition

<table>
<thead>
<tr>
<th>Skill Area</th>
<th>Condition</th>
<th>Decrease</th>
<th>No Change</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Overall</td>
<td>20.5%</td>
<td>48.9%</td>
<td>30.6%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>26.4%</td>
<td>43.6%</td>
<td>30.0%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>15.1%</td>
<td>53.8%</td>
<td>31.1%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>19.8%</td>
<td>49.5%</td>
<td>30.7%</td>
</tr>
<tr>
<td>II</td>
<td>Overall</td>
<td>10.7%</td>
<td>81.0%</td>
<td>8.3%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>10.9%</td>
<td>83.6%</td>
<td>5.5%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>12.3%</td>
<td>76.4%</td>
<td>11.3%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>9.0%</td>
<td>82.9%</td>
<td>8.1%</td>
</tr>
<tr>
<td>III</td>
<td>Overall</td>
<td>9.5%</td>
<td>69.7%</td>
<td>20.8%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>10.0%</td>
<td>72.7%</td>
<td>17.3%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>9.4%</td>
<td>69.8%</td>
<td>20.8%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>9.0%</td>
<td>66.7%</td>
<td>24.3%</td>
</tr>
<tr>
<td>IV</td>
<td>Overall</td>
<td>16.8%</td>
<td>59.9%</td>
<td>23.3%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>16.4%</td>
<td>59.1%</td>
<td>24.5%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>19.8%</td>
<td>56.6%</td>
<td>23.6%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>14.4%</td>
<td>64.0%</td>
<td>21.6%</td>
</tr>
<tr>
<td>V</td>
<td>Overall</td>
<td>25.1%</td>
<td>51.4%</td>
<td>23.5%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>27.3%</td>
<td>53.6%</td>
<td>19.1%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>26.4%</td>
<td>47.2%</td>
<td>26.4%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>21.6%</td>
<td>53.2%</td>
<td>25.2%</td>
</tr>
<tr>
<td>VI</td>
<td>Overall</td>
<td>11.3%</td>
<td>75.5%</td>
<td>13.2%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>10.0%</td>
<td>78.2%</td>
<td>11.8%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>12.3%</td>
<td>75.5%</td>
<td>12.2%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>11.7%</td>
<td>73.0%</td>
<td>15.3%</td>
</tr>
<tr>
<td>VII</td>
<td>Overall</td>
<td>20.5%</td>
<td>44.3%</td>
<td>35.2%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>25.5%</td>
<td>42.7%</td>
<td>31.8%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>23.6%</td>
<td>45.3%</td>
<td>31.1%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>12.6%</td>
<td>45.0%</td>
<td>42.4%</td>
</tr>
<tr>
<td>VIII</td>
<td>Overall</td>
<td>21.7%</td>
<td>37.6%</td>
<td>40.7%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>23.6%</td>
<td>43.6%</td>
<td>32.8%</td>
</tr>
<tr>
<td></td>
<td>Google Earth</td>
<td>19.8%</td>
<td>34.0%</td>
<td>46.2%</td>
</tr>
<tr>
<td></td>
<td>SC MAPS</td>
<td>21.6%</td>
<td>35.1%</td>
<td>43.3%</td>
</tr>
</tbody>
</table>

These frequency tables reveal some interesting descriptive statistics about changes in STAT scores by different conditions. Out of the eight spatial thinking skill areas, students in the Google Earth group improved scores the highest in four skill areas, students in the SC MAPS group increased the highest in three of the skill areas, and
students in the control group increased the highest in one skill area. As expected, students in the control group improved the least in the majority of skill areas. Students in the Google Earth group increased in comprehending orientation and direction (skill area I), comparing map information to graphic information (skill area II), correlating spatially distributed phenomena (skill area V), and comprehending geographic features represented as points, lines, or polygons (skill area VIII). Students in the SC MAPS group increased in choosing the best location based on several spatial factors (skill area III), mentally visualizing 3D images based on 2D information (skill area VI), and overlaying and dissolving maps (skill area VII). Surprisingly, students in the control group increased the most in imagining a slope profile based on a topographic map (skill area IV). Students in the control group increased the least in six of the eight skill areas, while students in the Google Earth group increased the least in skill area VII (Overlaying and Dissolving Maps) and students in the SC MAPS group improved the least in skill area IV (Imagining a Slope Profile Based on a Topographic Map). Showing the least decrease in scores among groups in each skill area, students in the SC MAPS group decreased the least in five skill areas, followed by students in the Google Earth group decreasing the least in two skill areas, and students in the control group decreasing the least in one skill area.

Skill Area I: Comprehending Orientation & Direction

More specifically, a larger percentage of students in the Google Earth group (31.1%) increased their STAT score compared to students in the SC MAPS (30.7%) and control groups (30.0%). Of all the conditions, the students in the Google Earth group also showed the lowest proportion of decreases in scores for this skill area.
Skill Area II: Comparing Map Information to Graphic Information

A larger percentage of students in the Google Earth group (11.3%) increased their STAT score compared to the students in the SC MAPS (8.1%) and control groups (5.5%). In this skill area, the students in the SC MAPS group showed the lowest proportion of decreases in scores.

Skill Area III: Choosing Best Location Based on Several Spatial Factors

A larger percentage of students in the SC MAPS group (24.3%) increased their STAT scores compared to the students in the Google Earth (20.8%) and control groups (17.3%). In this skill area, the students in the SC MAPS group showed the lowest proportion of decreases in scores.

Skill Area IV: Imagining a Slope Profile Based on a Topographic Map

A larger percentage of students in the control group (24.5%) increased their STAT scores compared to the students in the Google Earth (23.6%) and SC MAPS groups (21.6%). In this skill area, the students in the SC MAPS group showed the lowest proportion of decreases in scores.

Skill Area V: Correlating Spatially Distributed Phenomena

A larger percentage of students in the Google Earth group (26.4%) increased their STAT scores compared to the students in the SC MAPS (25.2%) and control groups (19.1%). In this skill area, the students in the SC MAPS group showed the lowest proportion of decreases in scores.
Skill Area VI: Mentally Visualizing 3D Images Based on 2D Information

A larger percentage of students in the SC MAPS group (15.3%) increased their STAT scores compared to the students in the Google Earth (12.2%) and control groups (11.8%). In this skill area, the students in the control group showed the lowest proportion of decreases in scores.

Skill Area VII: Overlaying and Dissolving Maps

A substantially larger percentage of students in the SC MAPS group (42.4%) showed an increase in their STAT scores compared to the students in the control (31.8%) and the Google Earth groups (31.1%). The largest difference between conditions exists in this skill area when comparing the percentage of students who increased their scores in the highest performing (SC MAPS) condition versus the next highest performing (control) condition (10.3%). Of all the conditions, the students in the SC MAPS group also showed the lowest proportion of decreases in scores for this skill area.

Skill Area VIII: Comprehending Geographic Features Represented as Point, Line, or Polygon

A larger percentage of students in the Google Earth group (46.2%) increased their STAT scores compared to the students in the SC MAPS (43.3%) and control groups (32.8%). In this skill area, the students in the Google Earth group showed the lowest proportion of decreases in scores. Overall, students showed the highest percentage of increase (40.7%) in their scores in this skill area.

Statistical Significance of the Spatial Thinking Skill Areas

An analysis of variance (ANOVA) was then run for each of the eight spatial thinking skill categories to ascertain if there were statistically significant differences in
any particular skill area. The change in the specific spatial thinking skill served as the
dependent variable with the three different conditions of instructional delivery serving as
the independent variable. A Levene’s equal variance test was also run on each ANOVA
to test for equal variances. If there were significant differences on scores in any given
category, a one-tailed t-test for multiple comparisons (LSD) was then run to identify
where improvements occurred.

There were no statistically significant differences in any of the eight spatial
thinking skill categories. The most change from STAT A to STAT B was seen in the
Overlay and Dissolve category (VII), made up of Questions 9, 10, 11 and 12. The
difference from STAT A to STAT B in this group of questions was not found to be
statistically significant from STAT A to STAT B, $F(2, 324) = 2.976$, $p = .052$. However,
the multiple comparisons test (LSD) revealed that the students in the SC MAPS group
scored significantly higher than the students in the Google Earth ($p = .035$) and control
groups ($p = .036$) in this spatial skill category. If the confidence level in the ANOVA
were adjusted to 90%, test results would show significant differences between the three
conditions. Further testing in this category is warranted.

The Comprehending Geographic Features Represented as Point, Line, or
Polygon category (VIII) was made up of Questions 13, 14, 15 and 16. There were no
significant differences found in this category, $F(2, 324) = 2.489$, $p = .085$. It is important
to note that the ANOVA test lacks statistical reliability because the variances are unequal.
However, in considering the difference of means, there does seem to be a marginal
difference in the improvement of the Google Earth group compared to the control group
($p = .043$) scores. If the confidence level in the ANOVA were adjusted to 90%, there
would be significant differences between the three conditions. Further testing in this category is also warranted.

Results showed no significant difference, $F(2, 324) = 1.737, p = .178$, in the Orientation and Direction category (I), made up of Questions 1 and 2. The Comparing Map Information to Graphic Information category (II) consisted of Question 3 and no significant difference was found, $F(2, 324) = .394, p = .675$. Question 4 falls into the Choosing the Best Location Based on Several Spatial Factors category (III) and no significant difference was found in this question, $F(2, 324) = .613, p = .542$. It is important to note that the ANOVA test for this category lacks statistical reliability because the variances are unequal. Question 5 was placed into the Imagining a Slope Profile Based on a Topographic Map (IV) category and no significant differences were found, $F(2, 324) = .144, p = .866$. In the Correlating Spatially Distributed Phenomena (V) category, made up of Questions 6 and 7, no significant differences were found, $F(2, 324) = 1.499, p = .225$. Category VI, Mentally Visualizing 3-D Images Based on 2-D Information, was made up of Question 8 and had no significant differences, $F((2, 324) = .143, p = .867$.

There were no statistically significant differences in any of the 8 spatial thinking skill categories. However, the multiple comparisons tests revealed that students in the SC MAPS group scored significantly higher than the students in the Google Earth and control groups in the Overlay and Dissolve category. Additionally, there does seem to be a marginal difference in improvement in the Google Earth group compared to the control group in the Comprehending Geographic Features Represented as Point, Line, or Polygon category.
4.4 FINDINGS FROM THE STUDENT SURVEY

Students completed a basic questionnaire and attitudinal survey prior to engaging in the study. The survey is divided into two parts and consists of 14 total items. The first part of the instrument included 10 items and was measured on a 5-point Likert-type scale, which was rated by the participants from 1 (strongly disagree) to 5 (strongly agree). These items were used to gather basic information on student attitudes on learning about geographic content, working with computers, and using maps and as well as their ease in doing so. It also gathered information on student access to computers and the Internet outside of school. Containing four items, the second part was designed to gather information about the students’ travel experiences and the travel experiences of their parents, a possible influence on their spatial understanding. This part of the instrument required a response of yes, no, or don’t know.

Survey Item Data

The 14 items in the student survey were grouped into four categories based upon the type of information each item requested. The four categories of questions and the specific survey questions that were included in each category are shown in Table 4.5. The survey may be seen in its entirety in Appendix H.

Table 4.5 Student Survey Categories by Question

<table>
<thead>
<tr>
<th>Survey Category</th>
<th>Survey Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudes towards Geography</td>
<td>1, 2, 3, 4, 9, 10</td>
</tr>
<tr>
<td>Attitudes towards Technology</td>
<td>5, 6</td>
</tr>
<tr>
<td>Access to Technology</td>
<td>7, 8</td>
</tr>
<tr>
<td>Past Travel Experience</td>
<td>11, 12, 13, 14</td>
</tr>
</tbody>
</table>

Once placed in appropriate categories, the answers to questions were aggregated numerically. All of the questions in each of the categories except Past Travel Experience
were answered by a 5-point Likert-type scale. The first category, Attitudes towards Geography, contained six questions allowing a possible high score of 30 and possible low score of five for each student. The Attitudes towards Technology and Access to Technology categories contained two questions each allowing a possible high score of 10 and a possible low score of two for each student. The last category, Past Travel Experience, contained four questions. These questions were answered in three possible responses: yes, no, or don’t know. These answers were assigned the following numerical values: Yes responses = 1, No responses = -1, and Don’t Know responses = 0.

Min Max scaling, a type of normalization technique, was used to scale values between 0 and 1. It also creates a continuous, numerical variable that can be used in a correlation analysis. The following formula, where \( e_i \) equals the aggregated numerical score in each category,

\[
\text{Normalized } e_i = \frac{e_i - E_{\text{min}}}{E_{\text{max}} - E_{\text{min}}}
\]

It is expected that the higher the scores in each category of the student, the higher the spatial thinking skills will be. It is necessary to perform a bivariate correlation between the difference in STAT score (B-A) and student survey score by category in order to identify if there is a relationship between these survey categories and the conditions. The difference in STAT score (B-A) serves as the dependent variable while the student survey score by category acts as the independent variable. Then the normality of the distribution was checked for each category. Attitudes towards Geography was normally distributed, therefore a Pearson’s R was used to assess correlation. All other categories were not normally distributed; therefore a Kendall’s tau-b was used to assess correlation.
*Attitudes towards Geography by Condition*

Pearson’s R showed no correlation between the difference in STAT scores and the students’ attitudes towards geography (Table 4.6).

Table 4.6 Correlation of Improvements in STAT Score and Attitudes Towards Geography

<table>
<thead>
<tr>
<th>Condition</th>
<th>Correlation coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>R = .050</td>
<td>.184</td>
</tr>
<tr>
<td>Control</td>
<td>R = .026</td>
<td>.392</td>
</tr>
<tr>
<td>Google Earth</td>
<td>R = .088</td>
<td>.184</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>R = .026</td>
<td>.392</td>
</tr>
</tbody>
</table>

*Attitudes towards Technology by Condition*

Kendall’s tau-b showed no correlation between the difference in STAT scores and students’ attitudes towards technology in the total population and within the Google Earth and SC MAPS groups. However, there was a weak, positive correlation among the students in the control group (Table 4.7).

Table 4.7 Correlation of Improvements in STAT Score and Attitudes Towards Technology

<table>
<thead>
<tr>
<th>Condition</th>
<th>Correlation coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>τ = .041</td>
<td>.177</td>
</tr>
<tr>
<td>Control</td>
<td>τ = .134</td>
<td>.040*</td>
</tr>
<tr>
<td>Google Earth</td>
<td>τ = .036</td>
<td>.320</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>τ = -.023</td>
<td>.381</td>
</tr>
</tbody>
</table>

Significant * p ≤ .05

*Access to Technology by Condition*

Kendall’s tau-b showed no correlation between the difference in STAT scores and the students’ access to technology (Table 4.8).
Table 4.8 Correlation of Improvements in STAT Score and Access to Technology

<table>
<thead>
<tr>
<th>Condition</th>
<th>Correlation coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>$\tau = -0.012$</td>
<td>.398</td>
</tr>
<tr>
<td>Control</td>
<td>$\tau = -0.071$</td>
<td>.187</td>
</tr>
<tr>
<td>Google Earth</td>
<td>$\tau = 0.057$</td>
<td>.236</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>$\tau = 0.042$</td>
<td>.293</td>
</tr>
</tbody>
</table>

Past Travel Experience by Condition

Kendall’s tau-b showed no correlation between the difference in STAT scores and students’ past travel experiences in the Google Earth and SC MAPS groups. However, there was a weak, positive correlation among the students in the total population and within the control group (Table 4.9).

Table 4.9 Correlation of Improvements in STAT Score and Past Travel Experience

<table>
<thead>
<tr>
<th>Condition</th>
<th>Correlation coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>$\tau = 0.078$</td>
<td>.041*</td>
</tr>
<tr>
<td>Control</td>
<td>$\tau = 0.229$</td>
<td>.002*</td>
</tr>
<tr>
<td>Google Earth</td>
<td>$\tau = 0.072$</td>
<td>.179</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>$\tau = -0.015$</td>
<td>.422</td>
</tr>
</tbody>
</table>

Significant * p ≤ .05

Out of the four categories of questions included in the student survey, there was no correlation between the difference in STAT scores and students’ attitudes towards geography nor students’ access to technology. However, there was a weak, positive correlation between the differences in STAT scores and students’ attitudes towards technology among the students in the control group, as well as, a weak, positive correlation between the difference in STAT scores and students’ past travel experiences among the students in the total population and within the control group.

Demographic Data by Condition

Each student survey was pre-coded at the bottom of the page with the student number that identified the student. Following this number were several letters (G, R, L,
and SE) followed by blanks for teachers to fill in demographic data about that particular student so that the researcher was not exposed to student names. The teacher then reported the gender, race, academic level (College Preparatory or Honors), and special education status (yes or no) of the student. Special education status was represented by the presence of an Individual Education Plan (IEP).

Difference of means tests were then run for each of the four demographic variables to ascertain if there were statistically significant differences in any particular area. The difference in STAT score (B-A) served as the dependent variable with the demographic variables serving as the independent variables. A test was run for the total population, as well as, for each of the three conditions in each of the four demographic variables. A Levene’s equal variance test was also run on each difference of means test to test for equal variances. If there were significant differences on scores in any given category, a one-tailed t-test for multiple comparisons (LSD) was then run to identify where significant improvements occurred.

Gender Data by Condition

A t-test for independent samples was run for male and female students for the total population and for each of the three conditions. The test revealed that there were no significant differences between the two genders in any of the conditions (Table 4.10).

Table 4.10 Gender Differences by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>-.356</td>
<td>.722</td>
</tr>
<tr>
<td>Control</td>
<td>-.784</td>
<td>.434</td>
</tr>
<tr>
<td>Google Earth</td>
<td>-.247</td>
<td>.805</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>-.057</td>
<td>.954</td>
</tr>
</tbody>
</table>
Race Data by Condition

An analysis of variance (ANOVA) was run by condition on the four identified races within the study population: Asian, Black, Hispanic and White. There were no statistically significant differences shown in the results of the ANOVA (Table 4.11). However, the one-tailed t-test for multiple comparisons (LSD) for the total population identified that there was a significant difference between black students and white students. The test revealed that both groups of students improved, but white students scored higher than black students by 4.4% (p = .025).

Table 4.11 Race Differences by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>1.896</td>
<td>.130</td>
</tr>
<tr>
<td>Control</td>
<td>.766</td>
<td>.516</td>
</tr>
<tr>
<td>Google Earth</td>
<td>1.738</td>
<td>.181</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>1.259</td>
<td>.292</td>
</tr>
</tbody>
</table>

Academic Level Data by Condition

A t-test for independent samples was run for students in each of the two academic levels that were included in the study: College Preparatory and Honors. The test revealed that there were significant differences among the different levels of students (Table 4.12). A one-tailed t-test for multiple comparisons (LSD) for the total population identified that there was a significant difference between the students in the two academic levels. The test revealed that Honors students performed better than College Preparatory students. The overall mean score improved by 6.9% among the Honors students and by only 2.9% among the College Preparatory students. A one-tailed t-test for multiple comparisons (LSD) also revealed that Honors students in the SC MAPS group increased
their mean scores by 11% while College Preparatory students increased their mean scores by only 4.3%.

Table 4.12 Academic Level Differences by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>-2.289</td>
<td>.023*</td>
</tr>
<tr>
<td>Control</td>
<td>-1.061</td>
<td>.291</td>
</tr>
<tr>
<td>Google Earth</td>
<td>-0.965</td>
<td>.337</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>-2.359</td>
<td>.020*</td>
</tr>
</tbody>
</table>

Significant * p ≤ .05

Special Education Data by Condition

A t-test for independent samples was run to ascertain if there were any statistically significant scores between students who were identified as Special Education and those who were not. The test revealed that there were no significant differences between the two different classifications of students in any of the conditions (Table 4.13).

Table 4.13 Special Education Differences by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population</td>
<td>.149</td>
<td>.881</td>
</tr>
<tr>
<td>Control</td>
<td>-.082</td>
<td>.935</td>
</tr>
<tr>
<td>Google Earth</td>
<td>.045</td>
<td>.964</td>
</tr>
<tr>
<td>SC MAPS</td>
<td>.254</td>
<td>.800</td>
</tr>
</tbody>
</table>

Interaction Effects

A four-way ANOVA was run on all possible combinations of the four demographic variables (gender, race, level, special education status) as a precaution to rule out any possible interaction effects that might alter the interpretation of the previously discussed ANOVAs. No significant interaction effects were found in any combination of demographic variables.

The four-way ANOVA test was then repeated by adding the condition as a variable. A statistically significant difference was found between groups based on the
interaction of race, academic level, and condition, $F(3, 326) = 3.024, p = .030$. The sample was then stratified by each of the three conditions: the control, Google Earth, and SC MAPS groups, to identify where the significant difference occurred. Significant improvements were found within the control, $F(3, 109) = 3.211, p = .026$, and within the Google Earth groups, $F(2, 105) = 4.117, p = .019$. There were no statistically significant differences found within the SC MAPS group, $F(2, 110) = .457, p = .634$. Future research should be conducted to further study the interactions among race and academic level by conditions.

4.5 SUMMARY OF FINDINGS

The objective of this chapter was to determine whether spatial thinking skill development differs through different media and to identify what other barriers may influence spatial thinking skill development. This was investigated by analyzing the student scores on the STAT and by answers provided on the student survey.

The results from the STAT scores analyzed by condition show that all three groups - control, Google Earth, and SC MAPS - improved their scores from the pre-test, STAT A, to the post-test, STAT B. However, there was no statistically significant difference in the control group. Both intervention groups showed highly significant improvements on STAT B, with the SC MAPS group having a higher significant improvement.

The results from the STAT scores analyzed by question revealed that the percent correct increased on the majority of questions from STAT A to STAT B in all groups. The SC MAPS group increased on the most questions followed by the Google Earth group. As expected, the control group improved on the least amount of questions.
Collectively, students decreased the most on Questions 2 (Orientation and Direction), 3 (Comparing Map Information to Graphic Information), 6 (Correlating Spatially Distributed Phenomena), and 11 (Overlay and Dissolve). Students scored the highest on Question 3 (Comparing Map Information to Graphic Information) and the lowest on Question 12 (Overlay and Dissolve) in both versions of the STAT. Students improved the most on Question 4 (Choosing Best Location).

The results from the STAT scores analyzed by spatial thinking skill disclosed that out of the eight spatial thinking areas, students in the Google Earth group increased the most in four skills: comprehending orientation and direction (skill area I), comparing map information to graphic information (skill area II), correlating spatially distributed phenomena (skill area V), and comprehending geographic features represented as points, lines, or polygons (skill area VIII). Students in the SC MAPS group increased the most in three skills: choosing the best location based on several spatial factors (skill area III), mentally visualizing 3D images based on 2D information (skill area VI), and overlaying and dissolving maps (skill area VII). Students in the control group increased the most in one skill, imagining a slope profile based on a topographic map (skill area IV). The student intervention lessons did not focus on all of the 8 skill areas. Skills within skill areas I, II, III, IV, and VIII were all included in the intervention lessons. A further discussion of these skills and how they related to the student intervention lessons will be approached in Chapter 6.

The least amount of increase was seen in six skill areas by the students in the control group, one skill area by students in the SC MAPS group, and one skill area in the Google Earth group. Students showing the least amount decrease in scores were students
in the SC MAPS group in five skills, students in the Google Earth group in two skills, and students in the control group in one skill. It was also revealed that the students in the SC MAPS group had the highest margin of increase of any group in any skill level. Overall, students increased their scores more in skill area VIII than in any other skill area.

There were no statistically significant differences in any of the eight spatial thinking skill categories. Both categories, VII and VIII, were found not to have significant difference at the confidence level of 95%. However, if the confidence level were adjusted to 90%, there would be significant improvement in comparing scores. In considering the differences of means, there does seem to be a marginal improvement by the students in the SC MAPS group over students in the Google Earth and control groups in skill area VII (Questions 9, 10, 11 and 12) and students in the Google Earth group over students in the control group in the skill area VIII (Questions 13, 14, 15 and 16). It is important to discuss possible explanations why students who were taught by a particular media experienced higher improvements in specific skill areas. This discussion will be approached in Chapter 6. It is also important to note that the ANOVA test lacks statistical reliability in skill area VIII because the variances are unequal. Further testing in these categories is warranted.

The results from the STAT scores analyzed by demographic variables revealed that there were statistically significant differences between students in College Preparatory classes and Honors classes. Overall, between STAT A and STAT B, Honors students increased their scores 4% higher than College Preparatory students. In the SC MAPS group, Honors students increased their scores 6.7% higher than College Preparatory students. While there were no significant differences among the different
races involved in the study, results showed that overall, white students increased their scores 4.4% higher than black students. There were no statistical differences among gender or Special Education versus non-Special Educations students.

The results from the STAT scores analyzed by the student survey showed that there was no correlation between improvements on STAT scores and students’ attitudes toward geography. There was also no correlation found between improvements on STAT scores and students’ access to technology. While there was no correlation found between the improvements in STAT scores and students’ attitudes towards technology in the total population, the Google Earth and SC MAPS groups, there was a weak, positive correlation among the students in the control group. There was also a weak, positive correlation found between the improvements in STAT scores and students’ past travel experiences among students in the total population and within the control group.

The results from testing all possible combinations of the four demographic variables showed no significant interaction effects among any combination. When condition was added to variables, a statistically significant difference was found between race, academic level, and condition. Stratifying the sample by each of the conditions revealed that a significant difference occurred within the control and the Google Earth groups. There were no statistically significant differences found within the SC MAPS group. Future research is warranted in the interactions of race and academic levels by conditions.
CHAPTER 5

STUDENT AND TEACHER INTERVIEWS AND OBSERVATIONS

The previous chapter explored the quantitative findings of the two research questions posed in this study. The results showed that students in both intervention groups, Google Earth and SC MAPS, showed improvements in STAT scores over time. There was a slightly larger improvement within the students in the SC MAPS group over the students within the Google Earth group.

Included here is an analysis of the student and teacher interviews. These responses reveal some insights from the study that were not attainable through quantitative analysis. In addition, observations made by the researcher, during the intervention lessons, are discussed.

5.1 STUDENT INTERVIEWS

Following the completion of STAT B, 24 students from the intervention groups were interviewed about their experiences with the activities in the study. A random number generator was used to select two students from each of the twelve intervention classes. In order to develop a richer understanding of their experiences, this subset of students was invited to share their opinions about the activities.

Easiest Questions from STAT A

To ascertain the ease of STAT questions, students were supplied with a paper copy of the test to help them identify which question they deemed easiest out of the 16 questions. Out of 24 students, eight students (33.3%) argued that Questions 1 and 2 on
comprehending orientation and direction were the easiest. Seven students (29.2%) chose Question 3 on comparing map information to graphic information. Questions 6 and 8 on correlating spatially distributed phenomena and mentally visualizing 3D images based on 2D information, respectively, were selected by three students each (12.5%). Two students (8.3% each) selected Question 5 on imagining a slope profile based on a topographic map, and one student (4.2%) selected Question 9 on overlaying and dissolving maps (Table 5.1). Based on this small, random sample, students found the beginning of the test to be easier than the latter part of the test.

Table 5.1 Easiest STAT Questions – Student Interviews

<table>
<thead>
<tr>
<th>STAT Question</th>
<th>Skill Area</th>
<th>Student Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2</td>
<td>Orientation and Direction</td>
<td>33.3%</td>
</tr>
<tr>
<td>3</td>
<td>Comparing Map to Graphic Information</td>
<td>29.2%</td>
</tr>
<tr>
<td>6</td>
<td>Correlating Spatial Distribution</td>
<td>12.5%</td>
</tr>
<tr>
<td>8</td>
<td>Visualizing 3D Images Based on 2D</td>
<td>12.5%</td>
</tr>
<tr>
<td>5</td>
<td>Imagining a Slope Profile</td>
<td>8.3%</td>
</tr>
<tr>
<td>9</td>
<td>Overlay and Dissolve</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

* (n = 24)

After students were asked to identify which question in the STAT was the easiest, they were asked to convey what they thought was easy about it and to describe what strategies they used. All of the students who selected Questions 1 and 2 reported that the questions were easiest because the directions were simple and easy to understand. One student commented that the directions are “right there” and that no time had to be spent figuring out what the question was asking. Another student stated that they noticed the directional indicator did not have “north” pointing up in the typical manner, and thus was able to strategize using that detail. One student strategized that the question was easy if the compass was used. This student elaborated, “The compass is the first thing I look for on a map.”
Students who chose Question 3 as the easiest also reported that the question was easy to understand. One student stated that the large increase in the map was easy to identify and two other students commented that it was easy to see the gradual change because they “do this” in math class. Another student identified seeing the coloration difference and using the colors in the key as being helpful.

Students who identified Question 6 as the easiest again reported that it was easy to understand what the question was asking them to do. One student reported that “all you had to do was figure out which one was most alike.”

Students who identified Question 8 as the easiest shared similar explanations of why this question was easy. One student simply reported that the image is shown from above and it is easy to tell how it would look from the side while another one simply stated that it was easy to visualize things from above. One student explained “We did this in science. The lines helped me out and told how the mountain was going to look.”

The two students who chose Question 5 as the easiest question had different strategies on how to solve it. One student stated, “We learned about those lines in science. I remember that closer lines are steeper and have a higher elevation.” The other student reported simply looking at the numbers to locate higher elevations.

The only student who selected Question 9 as being the easiest stated that the shapes were what made it easy. In explaining the strategy that was used to answer the question, the student explained, “See how this part is black and this part is white? All you do is switch them and you get the answer.”
Most Difficult Questions from STAT A

In an effort to ascertain levels of difficulty on questions in the STAT, students were also asked to identify which question they deemed hardest out of the 16 questions. Seventeen students (70.8%) out of 24 found some combination of Questions 9, 10, 11, and 12 on overlaying and dissolving maps to be the most difficult. Out of those 17 students, nine students grouped all four questions together as the most difficult while eight of the students narrowed it down to either Questions 10 and 11 coupled together or Questions 11 and 12 coupled together. In addition to those students, Questions 4 and 6 were selected by two students each (8.3% each). Question 4 tested choosing the best location based on several spatial factors while Question 6 tested correlating spatial distributed phenomena. It should be noted that three students pointed to the directions page for Question 6, identifying the sample question used in the directions as the hardest question. Clearly, parts of the test’s design were confusing to students, as discussed further in Chapter 7. These students were informed that those were directions and not actual test questions, and therefore were asked to select another question as being the hardest. After being redirected, these three students (4.2% each) ultimately chose Questions 3, 7, and 8 as the most difficult. Question 3 tested comparing map information to graphic information, Question 7 tested correlating spatially distributed phenomena, and Question 8 tested mentally visualizing 3D images based on 2D information (Table 5.2).
Table 5.2 Most Difficult STAT Questions – Student Interviews

<table>
<thead>
<tr>
<th>STAT Question</th>
<th>Skill Area</th>
<th>Student Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>9, 10, 11, 12</td>
<td>Overlay and Dissolve</td>
<td>37.5%</td>
</tr>
<tr>
<td>11, 12</td>
<td>Overlay and Dissolve</td>
<td>20.8%</td>
</tr>
<tr>
<td>10, 11</td>
<td>Overlay and Dissolve</td>
<td>12.5%</td>
</tr>
<tr>
<td>4</td>
<td>Choosing Best Location</td>
<td>8.3%</td>
</tr>
<tr>
<td>6</td>
<td>Correlating Spatial Distribution</td>
<td>8.3%</td>
</tr>
<tr>
<td>3</td>
<td>Comparing Map to Graphic Information</td>
<td>4.2%</td>
</tr>
<tr>
<td>7</td>
<td>Correlating Spatial Distribution</td>
<td>4.2%</td>
</tr>
<tr>
<td>8</td>
<td>Visualizing 3D Images Based on 2D</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

* (n = 24)

The majority of students who were interviewed after the study chose some combination of Questions 9, 10, 11, and 12 to be the most difficult to answer. The students who chose these questions all had very similar responses to why they were difficult. Some of the statements were as follows:

“I just don’t get it. What do they mean?”

“It was just very confusing what they were asking. I’ve never learned this stuff before.”

“These shapes. I was just like what in the world.”

“These are ridiculous! I don’t understand because the way they were put together. These questions don’t make any sense.”

“I just don’t get what they are asking at all.”

“I understand the directions, but it’s just the first time I’ve seen anything like this so it’s pretty confusing.”

“I had no idea what to do. These just make absolutely no sense to me.”

Students who chose Question 4 as the most difficult both complained of the directions being too difficult to understand. Students who chose Question 6 also explained that it looked confusing and had trouble understanding the question. The
student who identified Question 3 stated that the question was difficult to understand. The student who identified Question 7 complained of not knowing how to read and understand the graph. The student who selected Question 8 reported that the perspective in which they were asked to use to answer the question was difficult.

*Exposure to STAT A*

When asked if exposure to the questions in STAT A helped them in the activities, 14 students (58.3%) replied affirmatively. Three of those students reported that the STAT A questions helped them at least “a little bit.” An additional five of those students elaborated that they had never seen questions like that before so that when they saw similar questions again it was more familiar to them. Another nine students (37.5%) reported that the STAT A questions did not help them on the activities by replying either “no” or “not really”. Only 1 student (4.2%) reported that it was unknown if the questions helped on the activities.

*Interest Level in the Activities*

When asked to describe the level of interest they experienced in completing the lessons on Charleston and Myrtle Beach, 16 students (66.7%) used the word “fun” to describe the activities. Some of these students disclosed that it was fun because the activities were different than normal schoolwork. Some noteworthy comments included:

“I liked the maps. It was better than Google Earth because you can hold it and turn it. It was more fun.”

“It was cool; definitely more fun than looking at a boring map on a piece of paper.”
“It was interesting. It was way better than looking at a map and more fun to mess around on a computer.”

“It was fun because you had to think. I felt smart.”

“The maps were fun, but not those tests we had to take!”

Another 5 students (20.8%) described the activities as simply “ok”, “alright”, or “a little better than normal.” One student stated, “It was alright. Geography isn’t really one of my favorites because I haven’t learned about it yet.” Another student described, “It was better than taking notes or doing worksheets because we got to find stuff and measure stuff.” The remaining three students (12.5%) reported that it was not something that they enjoyed or interested them. One student specified, “I don’t really like that map stuff, it’s confusing to me and when it tells me where to go, I have no idea.”

Level of Difficulty in the Activities

Students were asked to describe the level of difficulty or ease they experienced in answering the activity questions. Half of the students (50%) rated the activities as “easy.” One student reported, “The maps were easy to use because you could like touch it and turn it and see stuff easier.” Only one student (4.2%) described the activities as “difficult.” Another 11 students (45.8%) rated the activities as “medium” in difficulty. Some comments included:

“Once I read the questions over, I could understand what they were asking. You just had to really think.”

“Some of it was kind of easy, but a lot was kind of hard when it would talk about certain places, like a highway. It was kind of hard to pick out where they were.”
“Some were easier than others, but some were pretty tough. You really had to think, but I wouldn’t say it was hard.”

“I would say medium. They weren’t really hard, but they weren’t that simple. It made you think.”

**Most Commonly Used Tools in the Activities**

Initially students were asked which tools they used most frequently in answering the questions. Twelve of the students interviewed were in the Google Earth group while the other twelve were in the SC MAPS group. Specifically, if they were in the Google Earth group, students were asked if they used such tools as the “roads layer” even though they were asked not to. Students using SC MAPS were asked specifically if they ever turned the map to orient themselves to help them answer a question.

Many students reported commonly using more than one tool. Of the students in the Google Earth group, nine of them identified the ruler as one of the most used tools, eight of them identified that the zoom feature was commonly used. Only two students reported that the compass was often used. One student reported specifically not using the compass, while another reported that it was too difficult to use on Google Earth and therefore discontinued use of it. One student also specifically reported not using the ruler at all during the activities. Four of the 12 students admitted to using tools on Google Earth that they were asked not to use, such as “street view” or the “roads layer.”

Comments ranged from, “Yeah, I used it…but only after I was done answering questions” to “Yes, how else was I supposed to answer those questions?” The remaining 8 students followed the directions and did not use tools that they were asked not to use.
These comments might be useful in future studies to include certain elements on a map that people think they need to solve the problem.

Out of the twelve students who were in the SC MAPS group, all of them identified using the compass often in the activities while eight of them also identified using the scale. One student specifically reported not using the scale while two other students who did report using it, pointedly added that they did not use it very much.

Eleven of the 12 students reported turning the map to help orient them when answering questions. The amount of how often the map was turned ranged from “only on directional questions” to “on every question.”

Improvements from the Activities

When asked if they learned how to read and use maps better after completing the activities, 16 students (66.7%) reported affirmatively, seven students (29.2%) reported marginal improvement, and one student (4.2%) reported negatively.

Students were then asked if they thought exposure to the activities helped them perform any better on STAT B. Thirteen students (54.2%) thought that the activities helped them perform better on STAT B. Several interesting comments were shared:

“I know I did better because we had seen the questions before and now they made more sense.”

“I didn’t have to think quite as hard the second time, but I still had to think.”

“Some of the questions were clearer to me after the activities.”

Of those thirteen students, two of them explained that they thought they did better on some questions but not “the shape questions,” in reference to Questions 9-12. An
additional 4 students (16.7%) claimed that they thought the activities helped them at least slightly, while 7 students (29.2%) declared that the activities did not help them do better on STAT B. One student stated, “I don’t think I did any better or any worse. The same questions got me on both tests.”

Lessons Learned from the Activities

Many noteworthy responses were provided when students were asked what they thought they learned by completing the activities. Some common responses were that they better learned how to read maps, how to understand maps and recognize what they are viewing, and that they simply understood maps more because they got easier to read as they got more familiar with them. Four students explained that they learned to see the world with a different perspective through these activities, that it helped them see the world differently. Three students commented that they actually learned for the first time how to use a compass, while two students stated that they learned how to use a map scale for the first time. Two students reported that their orientation improved by simply realizing that “north” is not always facing up on a map. One student explained of how they now can differentiate between land that is developed from land that is undeveloped while another student commented on learning the meaning of a “block.” Another student elaborated that it was now easier to recognize a road or a building and distinguish what it was rather than being unsure of what was being viewed. Yet another student reported learning that simply turning a map can offer a different perspective. Another student explained that exposure to the maps encouraged the habit of observing more “stuff” on the map. Another student simply stated, “I don’t know what I learned really, but it got a lot easier.” Only one student reported not learning anything from the activities.
Observations from the Student Interviews

Several observations were noticed from the student interviews in addition to the responses to the interview questions. After taking the STAT, many students appeared to have a negative taste for maps in general, or of the concept of spatial thinking. One student commented, “That test was wack! This is geography?” This type of statement is problematic to the discipline of geography and to geography education because it reflects a poor perception of the field. Possibly these negative generalizations of geography would not be made if students were not as threatened by or turned off by the difficulty of the STAT.

Additionally, a common statement heard throughout the student interviews was the self-admitting statement by the student that he/she was not good at maps. It is uncertain whether this statement is true or simply perceived so by students. However, the frequency of the statement leads to the question of why the statement was made by several students. Is it due to a simple lack of map exposure or is it a deeper cognitive issue? Weeden (1997) suggests the concept of maps being drawn looking vertically down on an area is one that needs to be introduced and practiced because it is an unfamiliar viewpoint compared to the view from the ground. Further research should be conducted in this area.

Students who were taught using the Google Earth medium did not report using the compass tool as much as students did who were taught using the SC Maps medium. This difference in tool use could be that the students using Google Earth assumed that “north” was facing up. However, that assumption could prove incorrect if the student uses the rotation tool and thus could lead to false information. Furthermore, regardless of
the type of media, many students do not typically use the term “direction” when
describing the chosen path of a route. Instead they use the phrase “which way to go.” It
seems that the term “direction” is unlearned for many at this age of development.

5.2 TEACHER INTERVIEWS

Satisfaction with the Intervention Lessons

At the conclusion of the study, the two teachers that taught the intervention
lessons to their students were individually interviewed. Both teachers reported that their
level of satisfaction with the lessons was very high. They were both completely satisfied
with the layout of the lessons and described them as being well thought out with easy to
understand formatting for students to follow. The lessons were also described as being
very thorough and practical. Teacher 1 noted that the background knowledge provided
about Myrtle Beach and Charleston, which was included in the introduction to the
lessons, offered insight into the particular cities and allowed the students a better
understanding of the locations. Teacher 2 agreed with the background information being
interesting to the students as it related to historical topics that had previously been studied
in class which helped “set the stage” for the lessons.

Standards Alignment and Age Appropriateness

Additionally, both teachers agreed that the activities were very age appropriate
and were also very well aligned with the relevant South Carolina educational standards.
Teacher 1 explained that while it is not possible to go back to 1861 on Google Earth, one
might compare historical maps with the present landscape that Google Earth offers. He
added that students have to get the geography in order to understand the history and “see
the big picture.” Teacher 2 conveyed that the activities fit really well within his course
because looking at the physical geography helped the South Carolina history come alive to the students. He described how he had taught his class about how the Patriots in the Revolutionary War had used the sandbars to their advantage and now the students could see these landforms and make connections. He also noted that these activities fit in nicely with the state science standards as well.

Perceived Student Satisfaction with Intervention Lessons

Both teachers perceived that overall, students seemed very satisfied with the activities and most students enjoyed participating. Teacher 1 remarked that a large percentage of students enjoyed doing these activities more than they enjoyed the regular scheduled lessons in his class. Both teachers agreed that the students enjoyed doing something different, whether it is using the maps or the computer.

Level of Interest and Curiosity in Spatial Concepts

The level of interest and curiosity in spatial concepts among the teachers was somewhat different between the two teachers. Teacher 1 described that with the increasing shift to the digital age, he is worried about students learning spatial concepts with technology alone because some students struggle with technology. Furthermore, he suggests that there is a significant part of the population that does not have access to the technologies at home and therefore they might suffer with concepts more than other students. Regardless of the equal playing field, he worries that students will not know the skills as much as they will know the technology. He argues, “The skills could be lacking sometimes, but if students know how to use the technology then they can show that they have learned the skills or rather imply that they know the skills when they might not actually know them.” He also believes that the opposite effect is true in that students who
suffer with technology skills might in fact learn the spatial concept skills but because they are not strong in using technology, it may appear that they don’t know the spatial skills because they have difficulty in using the technology.

When asked about his level of interest and curiosity in spatial concepts, Teacher 2 revealed that he loves it and is intrigued by it. He explained that because he is so young in his teaching career and learning to juggle so many tasks, that spatial thinking concepts will enhance what is identified in the standards. He offered that it will provide “an added dimension to go beyond the black and white of the standards and will help students better visualize the settlement and development of our state and even of our world.”

Student interest and curiosity in spatial concepts was reported by both teachers to initially have gone “completely over their heads.” Their first introduction to these concepts was in taking the pretest, STAT A. Numerous students in both intervention groups complained of the test’s difficulty and vocally assumed that they could not do the work. Teacher 2 added that once students were presented with the lessons and “engaged in activities that were more understandable, they could see how it actually applies to geographers in real life and how they are faced with types of spatial questions that consider other factors such as wind direction. That’s when they began to better understand the big picture.” Both teachers agreed that for some students the sheer novelty of something so different was interesting and peaked curiosity.

*Level of Interest and Curiosity in Using Technology in the Classroom*

Levels of interest and curiosity among the two teachers in using and understanding technology in the classroom is growing. Teacher 1 reported, “It’s kind of a blur because some things are happening so fast, but I have enough tools for the classroom
although I think we are way behind in schools when it comes to technology.” He contended that he still struggles with the use of a lot of technology in the classroom for fear that many students don’t have equal access and therefore might not be as comfortable in using it as other students. Both teachers had previously used Google Earth before, but they both reported becoming much more familiar and comfortable using the technology the more they “played around” with it. Teacher 2 admitted that he didn’t know as much as he thought he did about Google Earth and would probably answer the questions about confidence in teaching with technology on the teacher survey a little bit differently now.

Student interest and curiosity in using and understanding technology was perceived by both teachers to be very high overall. Teacher 2 pointed out that he believes a lot of interest, confidence, and curiosity in technology among students is generational and that they don’t have to think about using it correctly, they just innately know how to use it. He added that he is not sure if students in general, appreciate how much technology they have and the capabilities it possesses.

**Student Comments and Questions**

Teachers were asked to comment on the most positive, negative, interesting, or surprising comments or questions they heard from students during the completion of the lessons. Teacher 1 found it surprising to hear students that he expected to struggle with the activities comment on how easy they thought it was, while students that he thought would have no difficulty in completing the activities visibly struggled or commented that they did not understand what to do. He noticed that the higher-level students had more difficulty with the digital version of the activities than they did with
the paper version. He found it interesting that students struggled with identifying roads as much as they did and argued that the issue could exist because they were not yet at the driving age and thus were not as familiar with roads and road maps yet. He even asked in each of his classes how many students had seen a road map that one would put in the glove box of an automobile and was shocked to find out that not one student had ever seen a common road map.

Teacher 2 found terminology issues, such as “density” and “correlation”, to be surprisingly difficult. He was stunned by the amount of terms that students were not familiar with in the lessons. Perhaps most surprising to the teachers was that many students did not know the term “city block.” A possible explanation is that these students live in a suburban area rather than a city designed with a grid pattern. Additionally surprising was the observation that many students did not turn the maps to orient themselves during the entire activity. He was alarmed that this would severely limit the student’s perspective. Similar to Teacher 1, another interesting issue that Teacher 2 reported was that during the Charleston activity, in both the paper and digital sessions, many students easily located Interstate 26 as it runs in a distinct north/south direction, but that many students struggled in locating Highway 17. He explained that students struggled because Highway 17 does not run east/west as directly as Interstate 26 in its respective direction. In addition, he added that perhaps the difficulty also arose because only a section of Highway 17 appeared to “look like” a major highway, whereas other sections of it were appeared narrower and thus not as easily identifiable.
*Most Challenging Aspects of Teaching with SC MAPS*

Teacher 1 conveyed that the most challenging aspect of teaching with SC MAPS was that students were not aware of what they were looking at from the aerial perspective. Some of the students struggled to see the difference between a highway and the inter-coastal waterway (land versus water). It did not register to students what a factory or industrialized area would look like from that view. Conversely, Teacher 2 argued that the most challenging aspect was in wanting to intervene when students weren’t orienting themselves properly. He suggested this desire was due to teacher instinct in steering students in the correct direction and prompting them when they are struggling.

*Most Challenging Aspects of Teaching with Google Earth*

According to Teacher 1, the most challenging aspect of teaching with Google Earth was getting students to stay focused and not explore other places on the application. Teacher 2 rationalized that the most challenging aspect was the use of the directional indicator and the zoom feature. He argued that the directional indicator was not as pronounced as it was in SC MAPS, and was therefore more difficult for students to locate and thus utilize in answering questions. The zoom feature easily caused confusion among students, as the different scale in which they were viewing the imagery could produce different answers in some questions. For example, the question that asked students to describe the change in water as “abrupt or gradual” was very apparent in the static view of SC MAPS, but appeared differently at different scales in Google Earth. If students did not use the zoom function, they did not get the question correct.
Both teachers valued the lessons and believed that they did help to improve the spatial thinking skills of students, as well as of themselves. Both teachers leaned towards the paper over the digital medium as their preference of best improving students’ spatial thinking skills. They argued that the paper medium worked the best for their students largely in part to issues with technology. Teacher 1 explained that it was easier for him to identify the difference and assess student understanding with the paper maps because he could hear them talking with each other, hear how they were reasoning, and see them touching, pointing and moving the map. He noted that with the digital maps, most students just clicked the mouse in silence and this action made it harder to assess student learning as well as student difficulties. He remarked that it was much easier for students to get sidetracked in the digital sessions than in the paper sessions because of the “bells and whistles” Google Earth possesses as opposed to the SC MAPS. He added that once one person in the class got sidetracked and made a comment about something that they were observing on the computer screen, it became like the domino effect in that more students began to lose focus on the task at hand.

Teacher 2 experienced similar technological issues with the digital session. He stated that many students struggled to find the basic directional indicator (compass) on Google Earth because it wasn’t as obvious as it appeared on the SC MAPS. He admitted that he liked the idea of students being able to touch and turn the map and having to utilize the scale to draw off distances and get a measurement rather than knowing how to find the ruler tool on Google Earth and trust it to compute the distance for you. He does not like the fact that with the click of a button when using Google Earth the operation
automatically completes the task for the user. He feels that this ability takes away human control but believes this attitude may change once he becomes more confident in the technology.

Preference of Media

Ultimately, when asked which medium they preferred, both teachers preferred the SC MAPS media better than the Google Earth media. When asked which media he preferred, Teacher 1 responded, “Maps. Hands down maps without a doubt because I can assess it much better. When they (students) get on a computer, it is hard to tell which one they actually understand more, the skill or the technology. They couldn’t tell whether the water was abrupt or gradual on Google Earth, so they just wanted to find a tool to give them the answer without thinking about it.” He also stated that he believed the students learned more with SC MAPS, but did not clarify which media the students seemed to prefer.

When asked the same question about preferred teaching media, Teacher 2 responded, “I will be using paper maps more because they relate more with history. Google Earth only goes back about 20 years, but I would like to use it to illustrate historical changes. It helps students see that these places are for real and not just something old drawn on a map.” He also stated that he observed both groups really enjoy what they were doing, but did not clarify which medium seemed to better improve spatial thinking.

5.3 OBSERVATIONS FROM THE LESSON INTERVENTIONS

Observing the subjects during the lesson implementations also revealed some significant insights. Most immediately noticeable was the vastly different management
styles between the two teachers participating in the intervention lessons. Teacher 1 commanded the classroom naturally with ease and respect from his students. There was a confidence that was exuded when interacting with students that allowed for a mutual admiration between students and teacher. Teacher 2 differed significantly in his style of teaching from Teacher 1 by teaching with a much more student-centered style. Students had more flexibility to talk and move freely about the classroom, however, this created some discipline issues in which valuable instructional time was lost. While both types of teaching have value, the engagement level of students as a whole was not as substantial as in the classroom of Teacher 1.

The background readings that were provided to introduce each study site of the lesson proved difficult for some students even though these lessons from SC MAPS were designed on for an eighth grade reading level. The students appeared to struggle with terminology in general. One common example was the term “block” as used in the Myrtle Beach lesson. Many students repeatedly asked for explanation of the meaning of this term. Another observation revealed that some students struggled with the terms “abrupt” and “gradual.” These terminology struggles were more noticeable in the College Preparatory classes than in the Honors classes.

One situation that was observed was that some students in the Google Earth group did not know the cardinal directions. The application only gives a “north” indicator and does not label the other three cardinal directions. Some students in this group confused “east” and “west” because they were not clearly identified as they were in SC MAPS.
Another observation made within the Google Earth group was that several students did not finish reading the questions clearly before wanting to locate an identified place on the map. For example, in the Charleston lesson, one question identified the Citadel Football stadium as being located at Point B. However, upon reading the words “Citadel Football Stadium,” some students immediately typed those words into the search bar so that the application would locate it for them, not yet realizing that the question, in fact, specifically identified the proper location. A similar observation was made when students engaged the “roads layer” feature of the application to identify Interstates that were not labeled. Rather than trying to locate them on their own, many students used the application tools to find the answer for them. These situations are prime examples of knowing how to manipulate the technology to do the “thinking”.

Students who participated in the SC MAPS group were observed not manipulating the map to help orient themselves to different directions. Some students never turned the map at all during the entirety of the lessons. Students in the SC MAPS group were observed using a very rudimentary way to measure distance. A scale was provided on the map for students to use, but rather than marking off distance on a sheet of paper by using the scale and then using the rewritten scale to measure distance somewhere on the map, some students would simply use their fingers to represent distance. Obviously, this technique is not as accurate, but does express a resourceful method of measuring distance.

Overall, many students were heard commenting that the second lesson was easier than the first lesson. This statement is interesting because some students participated in the Charleston lesson first, while other students participated in the Myrtle
Beach lesson first. These comments suggest that one lesson was not necessarily “easier”
than the other lesson, but that perhaps the second lesson seemed easier to the students
based off of a more developed sense of familiarity.

One notable statement was heard from a student when the teacher was going
over the strategies and answers to the Myrtle Beach lesson. A question in the lesson asks
students to imagine that they are sitting in a boat at “Point 6” in the Intracoastal
Waterway facing southwest. It asks them to identify which direction the waterway bends
if they are facing straight ahead. While the teacher was discussing strategies to determine
the correct answer, a student remarks, “This is not social studies!” This comment offers
an interesting insight into student perceptions of what they think broadly constitutes
social studies, but more specifically, what constitutes geography. These student
perceptions are worthy of future investigation.

5.4 SUMMARY OF FINDINGS

This chapter investigated the qualitative findings from student interviews,
teacher interviews, and lesson observations made by the researcher. The student
interviews offered comments and perspectives from individuals that were not accessible
through quantitative testing. Overall, students found the first three questions of the STAT
to be the easiest to answer. These questions specifically tested student spatial skills in
comprehending orientation and direction and comparing map information to graphic
information. Most all students found the four questions testing student spatial skills on
comprehending overlay and dissolve to be the hardest ones to answer on the STAT. A
majority of students interviewed expressed that exposure to the questions in STAT A
helped them have a better understanding when completing the activities, in addition to
expressing that it was fun to participate in the activities. Roughly half of the students being interviewed described the level of difficulty in completing the activities as “medium,” while the other half of the students described the activities as being “easy” to complete. Among the students in the Google Earth group, the ruler and the zoom tools were used the most. Among the students in the SC MAPS group, all of the students who were interviewed reported using the compass, while most reported using the scale. Almost all of the students stated that they turned the map in order to help them better orient themselves. The majority of students also stated that the activities not only helped them on STAT B, but helped them be able to read and understand maps better.

Both teachers reported being very satisfied with the intervention lessons that were designed for the study, labeling them age appropriate and well aligned with the state standards. In addition, they both agreed that the students enjoyed participating in the lessons. One teacher acknowledged that he loved the spatial thinking concept and was very intrigued by it, while the other teacher admitted that he was worried about technology’s increasing role in teaching spatial thinking concepts. The teachers agreed that the spatial concepts were initially over the students’ heads in terms of comprehension, but after they became more familiar with the activities, the sheer novelty of the activities was intriguing to them. Interest levels with technology in the classroom between the two teachers ranged from somewhat fearful to embracing it into the curriculum. Both teachers described challenges with both of the media, but ultimately regarded them both as valuable in the development of spatial thinking skills among students. The SC MAPS medium was preferred by both teachers.
CHAPTER 6

DISCUSSION

This dissertation research was designed to investigate whether instruction through different media, among other variables such as attitudes toward geography and technology, past travel experience, and demographic variables have an effect on the development of spatial thinking skills. This study addressed the research questions by analyzing the STAT scores of the study population as well as responses to the survey and interview questions. This chapter will discuss the findings that answer the research questions that have guided this study.

6.1 DISCUSSION OF STAT SCORES

Students in all three groups – the control, Google Earth, and SC MAPS – showed similar performance patterns by improving their scores from the pre-test, STAT A, to the post-test, STAT B. Expectedly, there was no statistically significant difference in the control group, but the fact that there was improvement could imply that simple exposure to maps included in the STAT and/or spatial thinking types of questions could produce an increase of tests scores. These results are supported by the NRC report (2006) that contends that spatial thinking should not be an add-on to the curriculum, but rather a missing link to be incorporated within the existing, standards-based curriculum. The activities in this study were designed to be integrated directly into the existing curriculum of “South Carolina: One of the United States” classes, but to incorporate a dimension for students to have the opportunity to think critically and spatially.
Both intervention groups showed highly significant improvements on STAT B. It is not surprising at all that students in both intervention groups improved significantly on test scores because they were exposed to the intervention lessons designed for this study. These findings suggest that when students are formally taught to think spatially, they will perform better than students who are not formally taught. Many researchers have claimed that geospatial technology use in the classroom does enhance student learning (Demers 1999; Furner and Ramirez 1999; Keiper 1999; Baker and White 2003; West 2003; Wiegand 2003; Moxie et al. 2004; Baker 2005; Shin 2006; NRC 2006; Milson and Earle 2007). The results of the study do not dispute that claim and further supports that existing research.

However, this study also revealed that students taught with paper maps (SC MAPS) had a higher significant improvement than students taught with digital maps (Google Earth). Students in the SC MAPS group improved their mean test scores by approximately 8.1% while students in the Google Earth group improved their mean test scores by approximately 5.9%. In addition, the students in the SC MAPS group improved on slightly more of the STAT questions than students in the Google Earth group, improving on 88% and 81.3% of questions, respectively. These findings do not support the notion that geospatial technologies are more effective than paper maps, but rather they are more in line with the research of Pederson, Farrell and McPhee (2005) that found digital maps to be effective but not more effective than paper maps.

This research design differs from Lee and Bednarz (2012) who tested and analyzed the percentage of correct answers in STAT A only between different age groups of test-takers. In this study, the increase in percentage of correct answers from STAT A
to STAT B was analyzed between the control and intervention groups. When analyzed by individual question, the results from the STAT scores revealed that there was an increase on percent correct on the majority of questions from STAT A to STAT B in all groups. The SC MAPS group showed an increase on one more question overall than the Google Earth group. As expected, the control group improved on the least amount of questions.

6.2 DISCUSSION OF STAT SCORES BY QUESTION

This study revealed that there was an obvious connection between the questions in which students tested best and worst, and the questions in which they chose as easiest and most difficult. Scores for all students were uniformly higher and lower for some questions. In both versions of the STAT students scored the highest on comparing map to graphic information (Question 3), followed by correlating spatially distributed phenomena (Question 6), and the lowest on overlaying and dissolving (Question 12), followed by mentally visualizing 3D images (Question 8). These results are fairly consistent with the results from Lee and Bednarz (2012) in which middle school students scored the highest on Question 6, followed by Question 3 and lowest on Questions 11 and 12 equally, followed by Question 8. The results of this study show that students improved the most when comparing map information to graphic information (Question 3) and correlating spatially distributed phenomena (Question 6). The student interviews suggest that notable improvements in these skill areas could be due to the fact that students are learning these skills in other academic areas, such as math and science. Interview responses also reported that students identified Questions 1 and 2 on comprehending orientation and direction as being the easiest followed closely by Questions 3 and 6. Perhaps students chose the first two questions as being the easiest because during the
interviews, they were given a copy of the test to help them remember which questions were asked and these two questions were located on the first page of the test. Additionally, many students assumed the first two questions were easy ones to answer based on simplicity of directions, but multiple students who claimed they were easy did not get them correct. This situation most likely occurred when students simply assumed that “north” was facing up when in fact it was facing south.

Students improved the least on overlaying and dissolving maps (Question 12) and mentally visualizing 3D images based on 2D information (Question 8). These questions focus more on geospatial concepts rather than simply spatial thinking skills (Bednarz and Lee 2012), thus this result is likely because of the lack of exposure to GIS and related geospatial concepts in the K-12 curriculum, particularly for middle school students. These results are also similar to the responses in the student interviews on which questions were classified as the most difficult. Students largely identified the most difficult question(s) as being the ones involving map overlay and dissolve (Questions 9-12). The students complained of not understanding the questions or what actions they needed to take in order to find the answer. Again, this confusion is likely magnified by the fact that students have not been exposed to these types of overlay and dissolve questions because they are not familiar with the techniques of GIS, nor were these skills utilized in the intervention lessons. Conversely, even though students did not perform well overall on Question 8, only one student that was interviewed identified it as being the most difficult. However, students were asked to identify the single most difficult question. The low response in reference to the difficulty of Question 8 most likely does not reflect its level of difficulty, but rather simply identifies that more students thought
the overlay and dissolve questions were more difficult than the question on mentally visualizing 3D images based on 2D information.

The most improvement from STAT A to STAT B was seen on Question 4, which asked students to choose the best location based on several spatial factors. The fact that this question showed evidence of the most improved is interesting because many students struggled with the difficulty of this question and some students who were interviewed chose this question as being the most difficult. This improvement is likely based on the exposure students had in the intervention lessons that directly utilized this skill. Improvement could, however, be linked to understanding the instructions to the question a little more clearly in the post-test. The directions to this question caused difficulty, even for adults, during the pilot testing of this study.

6.3 DISCUSSION OF STAT SCORES BY SKILL AREA

The questions were grouped according to the spatial thinking area addressed in each specific question and categorized by Lee and Bednarz (2012). Although there were no statistically significant differences in any of the eight spatial thinking skill categories, the results from the STAT scores analyzed by spatial thinking skill disclosed that out of these eight spatial thinking areas, students in the digital map group improved in more skill areas than the students in the paper map groups. Students in the Google Earth group increased the most in four skills: comprehending orientation and direction (skill area I), comparing map information to graphic information (skill area II), correlating spatially distributed phenomena (skill area V), and comprehending geographic features represented as points, lines, or polygons (skill area VIII). These findings are supported by a number of scholars (Demers 1999; Furner and Ramirez 1999; Keiper 1999; Baker and
It is possible that both the digital medium and technology confidence level played a role in these students performing better. Even though the teacher interviews reported these students were less focused as a whole than the students in the SC MAPS group, it is possible that they learned more spatial thinking skills by maneuvering around in Google Earth adjusting the orientation and scale of the image being viewed. Further research is needed to explore reasons why these students might perform better in a larger number of skill areas than those taught with paper maps.

Students in the SC MAPS group increased the most in three skills: choosing the best location based on several spatial factors (skill area III), mentally visualizing 3D images based on 2D information (skill area VI), and overlaying and dissolving maps (skill area VII). Surprisingly, students in the control group increased the most in imagining a slope profile based on a topographic map (skill area IV). Although the students in the SC MAPS group did not perform the highest in the majority of skill areas, they had the largest difference between conditions (10.3%) when comparing the percentage of students who increased their scores in the highest performing (SC MAPS) condition versus the next highest performing (control) condition in skill area VII. The students in this group also showed the least amount of decrease in scores in five of the eight skill areas. These findings support the existing research of Pederson, Farrell, and McPhee (2005) that found paper maps to be more effective than digital maps. Perhaps being able to manipulate and physically turn the map aided in these successful results. It is also possible that the fact that the scale remained static on the paper maps, unlike the
scale in Google Earth if the zoom feature is utilized, assisted in students being able to visually identify examples overlaying and dissolving maps more clearly.

The student intervention lessons did not focus on all of the eight skill areas. Skills within skill areas I (Orientation & Direction), II (Comparing Map Information to Graphic Information), III (Choosing Best Location), IV (Imagining a Slope Profile), and VIII (Comprehending Geographic Features) were all included in the intervention lessons. Out of the five skill areas that were included on the intervention lessons, the students in the Google Earth showed the most increase in skill areas I, II, VIII. The other skill area that the students in the Google Earth group showed the most improvement in was area V, but it was not included in the intervention lessons. Out of the five skill areas that were included on the intervention lessons, the students in the SC MAPS group showed the most increase in skill area III. The other two skill areas that the students in the SC MAPS group showed the most improvement in were areas VI and VII, but they were not included in the intervention areas. Surprisingly, out of the five skill areas that were included in the intervention lessons, skill area IV saw the most improvement from students in the control group who did not participate in the intervention lessons at all. Overall it is unclear why one intervention group did better or worse in a particular category than the other one and further research is necessary to facilitate the discovery of these reasons.

The fact that there were no statistically significant differences found in any of the eight spatial skill areas in the three conditions was not expected. Both categories, VII and VIII, were found not to have a significant difference at the confidence level of 95%. However, if the confidence level were adjusted to 90%, there would be significant
improvement in comparing scores. In considering the differences of means, there does seem to be a marginal improvement by the students in the SC MAPS group over students in the Google Earth and control groups in skill area VII (overlaying and dissolving maps). As previously stated, it is possible that because the scale remained static on the paper maps unlike the scale in Google Earth when the zoom feature is utilized, students were better able to visually identify examples of overlaying and dissolving more clearly. Jones et al. (2004, 97) argue, “The virtual space of a digital map is not the space we see around us. In real space objects do not exist in ‘layers’ which can be removed independently. We should not assume that the use of layering and other conventions are automatic and easy for learners…it is possible that the screen may reduce viewers’ ability to gain a holistic overview of space represented in the digital map.”

Additionally, there seems to be a marginal improvement by the students in the Google Earth group over students in the control group in the skill area VIII (comprehending geographic features represented as points, lines, or polygons). This marginal improvement of students in the Google Earth group is most likely linked to the fact that students in the Google Earth group were directly exposed to instruction on utilizing points, lines, and polygons while students in the control group were not exposed to this instruction. It is important to note, however, that the ANOVA test lacks statistical reliability in skill area VIII because the variances are unequal. Further testing in these categories is needed to discover the reasons why a particular medium yields different performance levels in spatial thinking skills in order to identify the most effective method for how students learn these skills. More specifically, suggested research should include why students taught via the paper maps medium improved better on overlaying and
dissolving maps and why student taught via the digital medium improved better on comprehending geographic features.

Overall, students increased their scores more in skill area VIII (comprehending geographic features represented as points, lines, or polygons) than in any other skill area. Again, one possible explanation for this improvement is that these terms and how they are represented on maps were specifically taught to students in the introduction segment of each intervention lesson. The terms were explained and examples were provided to show the application of each term on a map. This method of direct instruction could be more effective when it comes to student outcomes than non-direct instruction.

6.4 DISCUSSION OF STAT SCORES AMONG DEMOGRAPHIC VARIABLES

The results from the STAT scores analyzed by demographic variables revealed that there were statistically significant differences between students in College Preparatory classes and Honors classes. Overall, Honors students increased their scores 4% higher than College Preparatory students. Honors students in the SC MAPS group increased their scores 6.7% higher than College Preparatory students. One possible explanation for the higher performance among Honors students is that these students are perhaps exposed to more rigorous course work such as algebra based on their academic grouping and therefore have developed more abstract thinking and deeper spatial thinking skills. Further research should be conducted to determine why certain academic levels perform better than others.

While there were no significant differences among the different races involved in the study, the results showed that overall white students increased their scores 4.4% higher than black students. Despite research where evidence has been shown that males
outperform females in spatial thinking ability (Boardman 1990; Goldstein, Haldane, and Mitchell 1990; Casey et al. 1995; Hardwick et al. 2000), results from this study are similar to that of Bednarz and Lee (2011) and show no statistical differences among gender. A possible explanation for this gender insignificance is that there is conceivably more equal exposure to maps via smartphones and Internet mapping applications. Although there is no evidence that the students in this study have exposure to smartphones and Internet mapping applications, these technologies are becoming more and more ubiquitous and thus could be a possible explanation of this result. A question this result poses is: Will simple increased exposure to maps improve spatial thinking equally among genders in the future? Further exploration of this matter is justified. There were also no significant differences between Special Education versus non-Special Educations students.

The results from the STAT scores analyzed by the student survey showed that there was no correlation between improvements on STAT scores and students’ attitudes toward geography. Existing research suggests that geospatial technologies improve student attitudes, motivation, and achievement in geography learning (Keiper 1999; Baker and White 2003; West 2003). This study did not test for change in student attitudes, but rather investigated if student attitudes played a role in spatial thinking skill development. Therefore, the results of this study do not necessarily support nor diminish this existing research (Keiper 1999; Baker and White 2003; West 2003).

There was also no correlation found between improvements on STAT scores and students’ access to technology. While there was no correlation found between the improvements in STAT scores and students’ attitudes towards technology in the total
population and within the Google Earth and SC MAPS groups, there was a weak, positive correlation among the students in the control group. Without further exploration of student backgrounds, it is difficult to hypothesize why a small correlation existed only among students on the control group. Further exploration of the affects of student access and attitudes towards technology are suggested.

There was also a weak, positive correlation found between the improvements in STAT scores and students’ past travel experiences among students in the total population and within the control group. These results were anticipated based on the past research of Thorndyke and Hayes-Roth (1982) and Golledge (1999) that found spatial learning with direct, navigational experience is more successful than map learning. While direct, navigational experience is not necessarily the same as past travel experience, the findings of this research are similar to past findings, but do not directly support or diminish existing research. Consequently, more detailed research on spatial thinking skill acquisition and past student travel experiences should be conducted.

The results from testing all possible combinations of the four demographic variables showed no significant interaction effects among any combination. When condition was added to variables, a statistically significant difference was found between race, academic level, and condition. Stratifying the sample by each of the conditions revealed that a significant difference occurred within the control and the Google Earth groups. There were no statistically significant differences found within the SC MAPS group. Future research is warranted in the interactions of race and academic levels by conditions to determine if students of different races and academic levels learn spatial thinking skills differently in different conditions (paper versus digital). These variables
were included because of their availability to the researcher. A better variable might have been socio-economic status, which correlates more appropriately to academic level, access to technology, and travel. However, the socio-economic status of students was not available for this research.

6.5 DISCUSSION OF THE STAT

The use of the STAT as the baseline for this study was based on its validity and reliability. The questions addressed many of the spatial thinking skills and geospatial concepts identified by the Gersmehls (2007) and by Golledge, Marsh, and Battersby (2008). Overall, this assessment instrument is a helpful start in the quest to develop a valid and reliable assessment tool for spatial thinking skills. However, the STAT proved to be somewhat problematic in this study. First, there was no standard format in the design of the test and were often no directions that told the students how to answer the questions. Each type of question should have a clear set of directions that instructs the student on how to properly answer the question, a component essential for student comprehension (Green and Johnson 2010). For example, each question could read “circle the letter of the correct answer,” which would provide consistency for the student so that they may focus on the skill that the question is testing, rather than trying to figure out the directions of what is being asked of them. Thirteen out of the 16 questions in the STAT assume that the student will circle the appropriate multiple-choice letter, without the directions stating to do so, while the other three questions ask for the student to place a check mark by a series of multiple choice answers or somewhere on a map indicating the correct answer. Is it a coincidence that the three questions that had directions that differed from the norm (Questions 4, 9, and 10) were also selected as the hardest questions by a
majority of the students interviewed? It is unclear whether there is a correlation between difficulty of the question based on the skill tested or based on the directions to the question.

In addition, comments observed during the intervention lessons as well as in the student interviews provided evidence that the instructions and/or language used in several of the questions were unclear and confusing to many of the students. For example, the directions to Question 4 read:

“Find the best location for a flood management facility based on the following conditions. First, a possible site for a flood management facility should be within 60 feet of an existing electric line. Second, a possible site for a flood management facility should be located less than 220 feet. And last, a possible site for a flood management facility should be located in State Park or Public Land” (Lee and Bednarz 2012) (Figure 6.1).

Figure 6.1 shows Question 4 of the STAT. This question asks students to select an ideal location combining three spatial criteria, but it is much too verbose and does not provide clear directions on how to report the answer. The directions and the instructions for how to physically mark the selected correct answer should be in one location on the page to limit confusion. It would be more suitable if the directions were slightly altered and the conditions were provided in bullet format.
DIRECTIONS: Find the best location for a flood management facility based on the following conditions. First, a possible site for a flood management facility should be within 60 feet of an existing electric line. Second, a possible site for a flood management facility should be located less than 220 feet. And last, a possible site for a flood management facility should be located in State Park or Public Land.

4. Mark √ on the best site (A–E) for the flood management facility on the map above.

Figure 6.1 STAT, Question 4
For example:

Find the best site for a flood management facility based on the following three conditions:

- The site must be located within 60 feet of an existing electric line.
- The site must be located less than 220 feet of elevation.
- The site must be located in a State Park or Public Land.

Circle the letter of the best site for the flood management facility.

Another design issue exists with Question 6. The directions are given on one page with a provided example and the actual question is given on the next page. This design layout is problematic and its use has been advised against in educational assessment research (Green and Johnson 2010). Furthermore, out of the small sampling of twenty-four students that were interviewed, three identified the example provided in the instructions for Question 6, rather than the actual question itself, as being the most difficult question on the test. These responses serve as evidence that the directions were not clear on this particular question if they thought that the example was the question itself. Figure 6.2 shows the directions and provided example of Question 6. Figure 6.3 shows Question 6, which was printed on a separate page from the directions to the question.
DIRECTIONS: Your job is to find maps that have spatial correlations. For example, map (B) and map (D) have positive correlation (similar patterns).

Example

Figure 6.2 STAT Directions and Example, Question 6
6. Find a map (A~F) having a strong positive correlation with the map on the left. (Choose closest one.)
Questions 9 and 10, which were identified by the majority of students interviewed as being some of the hardest questions on the test, also have unclear language in the example directions. It is unclear whether students found more difficulty in the wording of the shape formulas that the example provided, or the sheer abstractness of the process of overlaying and dissolving the shapes. These questions ask students to solve several questions based on a provided example. The example shows five scenarios in which two shapes are overlayed or dissolved thus creating a third shape. Figure 6.4 shows the directions and the provided example for Questions 9 and 10 as well as the questions themselves.

Redesigning the questions by providing clearer language and improving the interface on the page by providing better layout design to help students understand the questions could easily rectify these usability issues on the identified questions. Tomaszewskiet al. (Forthcoming) have used the STAT in their research and have experienced similar difficulties with its usability. They have made helpful modifications to the STAT such as providing clear directions for test questions and a more user-friendly design layout for specific questions to help better understand the questions. However, this modified version of the STAT was not available during this research project. It is important to note that the original STAT was primarily developed for secondary and college students although middle school students were tested in the original implementation of this test (Lee and Bednarz 2012).
Figure 6.4 STAT, Questions 9 and 10

Perhaps the most problematic issue was the verbal discontent expressed by many students about the STAT. These comments were observed in both the
administration of the intervention lessons and in the formal student interviews. Of utmost concern is whether or not the difficulty of the STAT put a poor taste of spatial thinking and geography in general into the minds of the students as both teachers eluded to in their interviews. Although the majority of the students interviewed reported that they enjoyed participating in the activities in the intervention lessons, students were more vocal about their discontent with participating in the STAT.

6.6 DISCUSSION OF TEACHER INTERVIEWS

Although both teachers described challenges with both of the different media, they ultimately regarded both the paper and digital media as valuable in the development of spatial thinking skills among students. Supporting the research of Hurst and Clough (2013) and Pedersen, Farrell, and McPhee (2005), which have established that there is a greater preference for paper maps by both geographic experts and students, respectively, the SC MAPS medium was preferred by both teachers in this study. Both teachers expressed concern that students as a whole are not as exposed to traditional maps as they once were in classrooms and in life in general. Garfield best expresses this concern: “There is something valuable about getting lost occasionally, even in our pixilated, endlessly interconnected world. Children of the current generation will be poorer for it if they never get to linger over a vast paper map and then try in vain to fold it back to its original shape. They will miss discovering that the world on a map is nothing if not an invitation to dream” (2012, 1). The confidence levels the teachers possessed about teaching with technology also likely influenced this paper map preference. Interest levels with technology in the classroom between the two teachers ranged from somewhat fearful to embracing it into the curriculum. However, the teacher who embraced using and
teaching with technology reported being very confident in teaching with technology on the survey, but expressed in the interview that he in fact was not as confident as he initially perceived himself to be and experienced some frustrations in teaching with the Google Earth application. Observations and interview responses indicated that the struggles with technology were more pronounced than the struggles with the SC MAPS with both teachers. In turn, this most likely influenced why they both teachers preferred the paper medium. Furthermore, the student focus issues in the Google Earth group also played a role in which media teachers prefer. If a particular medium interrupts classroom control and therefore student learning, it is easily discarded as ineffective and will in turn be used less frequently. It is important to point out that it is possible that teachers will teach with whichever medium they feel most confident in teaching, regardless of the documented benefits of another medium.

6.7 SUMMARY

This chapter has discussed the findings that answer the research questions that guided this study. This dissertation research was designed to investigate whether different media, among other variables such as attitudes toward geography and technology, past travel experience, and demographic variables have an effect on the development of spatial thinking skills. Based on the findings of this study, students in both media showed improvement in spatial thinking skills, however, the paper media proved to have a slight advantage over the digital media when evaluating improvements on student spatial thinking skills.
CHAPTER 7

CONCLUSIONS AND FUTURE RESEARCH

This final chapter provides a summary of the research findings on the influence of different media, among other variables, on student spatial thinking skill acquisition presented in earlier chapters. Also discussed are some concluding thoughts on the issues addressed in this research. These issues include determining if spatial thinking skill development differs between paper and digital map instruction; investigating whether spatial thinking skill development differs based on attitudes toward geography, past travel experience, or demographic variables; and exploring if there are any interaction effects among any of the variables related to the different instructional media. This chapter ends with a discussion of the limitations of this study and some ideas for future research that the findings suggest.

7.1 SCOPE OF RESEARCH

The purpose of this study was to examine if spatial thinking skill development differs between analog and digital map instruction and to investigate if any other variables effect spatial thinking skill acquisition. Two specific research questions were posed:

1. Does spatial thinking skill development differ between analog (paper) and digital map instructional delivery?
2. Does spatial thinking skill development differ based on attitudes toward geography, past travel experience, or demographic variables such as gender, and are there interaction effects among them related to different instructional media?

This dissertation research addressed the above questions by analyzing the differences in STAT scores among students. The analysis progressed through an investigation of STAT scores analyzed by condition, STAT question, and spatial thinking skill area. Finally, the relationship between student survey responses and STAT score improvement was explored. Survey responses included attitudes towards geography and technology, access to technology, and past travel experience. Demographic variables such as gender, race, academic level, and special education status were also explored.

Influence of Different Media on Student Spatial Thinking Skill Acquisition

It was expected that both media would increase spatial thinking skill development in students. However, it was also anticipated that students who are taught using the paper maps would have a higher increase in spatial thinking skills than those students taught with digital maps. When analyzing the difference in STAT scores among students by condition, there was a highly significant improvement in overall scores from STAT A to STAT B. The Google Earth and the SC MAPS intervention groups both showed highly statistically significant differences. Although there was a highly significant improvement in both instructional intervention groups, the measurable improvement was more in the SC MAPS group than in the Google Earth group. There were no statistically significant differences among STAT scores in the control group.

The overall correct answer percentages for each question in both STAT A and STAT B were also investigated. Students improved their scores from STAT A to STAT
B on 12 of the 16 questions in both the total study population and in the control group. Students improved their scores from STAT A to STAT B on 13 of the 16 questions in the Google Earth group and 14 out of 16 questions in the SC MAPS group.

A frequency table was run for all three conditions in order to evaluate change in scores in each of the eight skill areas. Out of the eight spatial thinking skill areas, students in the Google Earth group improved scores the highest in four skill areas, students in the SC MAPS group increased the highest in three of the skill areas, and students in the control group increased the highest in one skill area. As expected, students in the control group improved the least in the majority of skill areas. Students in the Google Earth group increased in comprehending orientation and direction (skill area I), comparing map information to graphic information (skill area II), correlating spatially distributed phenomena (skill area V), and comprehending geographic features represented as points, lines, or polygons (skill area VIII). Students in the SC MAPS group increased in choosing the best location based on several spatial factors (skill area III), mentally visualizing 3D images based on 2D information (skill area VI), and overlaying and dissolving maps (skill area VII). Surprisingly, students in the control group increased the most in imagining a slope profile based on a topographic map (skill area IV).

Additionally, there were no statistically significant differences in any of the eight spatial thinking skill categories. However, if the confidence level was adjusted from 95% to 90%, then students in the SC MAPS group would have scored significantly higher than students in the Google Earth and control groups in the Overlay and Dissolve category (VII). Furthermore, if the confidence level was adjusted from 95% to 90%, then
students in the Google Earth group would have scored significantly higher than the students in the control group in the Comprehending Geographic Features category (VIII).

*Other Influences on Student Spatial Thinking Skill Acquisition*

Many variables may contribute to how a student best learns spatial thinking skills. It was expected that the more favorable the student attitudes towards geography, the higher the spatial thinking skill development would be. It was also assumed that more past travel experience in students would equate to higher spatial thinking skill development. Additionally, it was also anticipated that males would develop better spatial thinking skills and improve upon existing skills better than females.

The results from the STAT scores analyzed by the student survey showed that there was no correlation between improvements on STAT scores and students’ attitudes toward geography. There was also no correlation found between improvements on STAT scores and students’ access to technology. While there was no correlation found between the improvements in STAT scores and students’ attitudes towards technology in the total population, the Google Earth and SC MAPS groups, there was a weak, positive correlation among the students in the control group. There was also a weak, positive correlation found between the improvements in STAT scores and students’ past travel experiences among students in the total population and within the control group.

The results from the STAT scores analyzed by demographic variables revealed that there were statistically significant differences between students in College Preparatory classes and Honors classes. Overall, Honors students increased their scores higher than College Preparatory students. In the SC MAPS group, Honors students increased their scores higher than College Preparatory students. While there were no
significant differences among the different races involved in the study, results showed that overall, white students increased their scores slightly higher than black students. There were no statistical differences among gender or special education versus non-special educations students.

The results from testing all possible combinations of the four demographic variables showed no significant interaction effects among any combination. When condition was added to variables, a statistically significant difference was found between race, academic level, and condition. Stratifying the sample by each of the conditions revealed that a significant difference occurred within the control and the Google Earth groups. There were no statistically significant differences found within the SC MAPS group.

7.2 CONCLUSION: FINDINGS AND GENERALIZATIONS

A primary objective to this research was to determine if spatial thinking skill development differs between paper and digital map instruction. This study determined that spatial thinking skill development does differ between the two types of media. Students taught by both media showed improvements in spatial thinking skills. Overall, paper map instruction was found to develop spatial thinking skills among students slightly better than digital map instruction when analyzing STAT score improvements by condition and by question. These findings support previous research and would likely hold true in other educational settings. Although there were no statistically significant differences in any of the eight skill areas when analyzing STAT score improvements by skill area, the digital map instruction showed improvements in more spatial thinking skill areas than the paper map instruction. However, while past research has established that
both paper maps and geospatial technologies enhance student learning, this study did not find that geospatial technologies necessarily enhance spatial thinking better than paper maps.

The second objective was to explore whether spatial thinking skill development differed based on attitudes toward geography, past travel experience, or demographic variables such as gender. There were no correlations between spatial thinking skill development and attitudes towards geography and technology or access to technology. While past research has demonstrated that geospatial technologies improve student attitudes, motivation, and achievement in geography learning, this study demonstrated that there was no correlation between improvements on STAT scores and students’ attitudes toward geography. A small correlation was found between student spatial thinking acquisition and past travel experiences of students, which also supports previous research. Additionally, this study established a small correlation between student spatial thinking skill acquisition and student attitudes toward technology. Despite past research that establishes males outperform females in spatial thinking ability, this study demonstrated that there were no correlations between gender and spatial thinking skill acquisition. There were also significant correlations found between student spatial thinking skill acquisition and academic levels. This study established that Honors students performed better than College Preparatory students.

The final objective was to explore if there were any interaction effects among any of the variables related to the different instructional media. There were no significant interaction effects among any combination. However, when condition was added to the variables, this study did find a significant difference between race, academic level, and
condition. Significant improvements were found within the control and Google Earth groups. There are many factors that may influence spatial thinking in individuals. This study has shown that both media, paper and digital, have their own benefits and weaknesses, but ultimately both assist in improving spatial thinking skill acquisition among students. Both spatial thinking and geospatial technologies have emerged as critical parts of today’s contemporary society. However, this study demonstrates the importance of the use of paper map instruction as a complementary instructional tool to digital map instruction. Digital maps should be utilized in the K-12 curriculum, but not at the expense of the more traditional, paper maps.

7.3 LIMITATIONS OF THIS STUDY

As with most research, this study has a number of limitations that must be acknowledged. One immediate limitation was the time frame in which the school approved research to be conducted. The eighth grade course that was utilized in the study is statewide tested (PASS) and therefore has a set schedule in the last month of the school schedule. Even though the curriculum designed for this study was standards-based, the school would only grant approval for this work to be conducted after students completed testing. The obvious constraint here is that time to conduct the study was limited between PASS testing completion in early May, and the end of the school year in early June. Exam schedules by individual teachers also had to be taken into consideration when planning times for the study activities.

Due to these time constraints, computer access at the study site was also very limited. Only one computer lab existed for the entire middle school and scheduling time
slots to use the lab were limited. This situation made it impossible for all four eighth
grade social studies teachers to be involved in the intervention lessons in the study.

Despite its reliability and validity over other spatial thinking assessments, the
STAT itself had flaws that made for difficult analysis. As discovered from the interviews,
many students misunderstood several questions in the test, making many responses
appear to be only haphazard guesses based in frustration. It is unclear how these at times
vocal frustrations with the STAT in general affected attitudes toward participation in the
study. It is also unknown how many answers were simply guesses and thus do not reflect
skill development.

In an effort to maintain equivalent interventions, precaution was taken in the
design of the lessons to prevent students in the Google Earth group from using the
oblique view by zooming in too closely. Google Earth has a function that turns this
feature off and therefore prevents the user from viewing the imagery from the oblique
view. However, when this feature was selected, it did not turn this capability off. This
issue was investigated with several GIS specialists to no avail.

In a study containing a survey or interviews, there arises the question of honesty.
While there were no indications that would suggest any student or teacher was less than
forthright in their responses, it is always a possibility that answers were altered from the
truth in order to be viewed as a higher achieving student or a more superior teacher.

The difference in management styles between the teachers was quite evident
during the implementation of the intervention lessons. This disparity may have caused
unintentional differences in the actual lesson interventions, thus causing a discrepancy in
responses to certain STAT questions. It is possible that students in one teacher’s class
were exposed to a higher quality of interventions simply because the class was better managed in terms of discipline.

One final possible limitation of this study is that both teachers in this study are classified as Digital Immigrants rather than Digital Natives (Prensky 2001). Digital Immigrants are people who were not born into the digital world, but at some point in their lives, usually later in life, have adopted many aspects of new technology. Conversely, Digital Natives are people who were born in the digital world and thus are ‘native’ to the digital language of computers, video games, and the Internet. Prensky argues that “Digital Immigrant instructors, who speak an outdated language (that of the pre-digital age), are struggling to teach a population that speaks an entirely new language” (2001, 2). The teachers in this study could have a bias toward preference of paper map use over digital map use simply because they are Digital Immigrants.

7.4 DIRECTIONS FOR FUTURE RESEARCH

*STAT Design Modifications*

Based on the results of this study, future research considerations are warranted. This study answered several questions but poses many others suitable for future research. One important area for continued investigation is the STAT. While it serves as a pioneer in assessments on spatial thinking that are reliable and valid, there are some modifications that would make it more user friendly. For example, several questions were unclear in the directions and misunderstood by many students. Some students even thought that the sample question in the directions for one of the questions was an actual question. Tomaszewskietal et al. (Forthcoming) seemed to be heading in this direction by making modifications to the STAT. These issues should continue to be improved upon in
future work. In addition, while the test was primarily designed for undergraduate students, it should be adjusted to allow for multiple ages to easily participate. Furthermore, several age appropriate designs could be developed.

**SC MAPS Curriculum Redevelopment**

The slight increase in improvement of the students in the SC MAPS group over the students in the Google Earth suggests that there is a need to update the existing SC MAPS imagery and curriculum. The present imagery is severely dated having been produced in 1989. In addition, the imagery is infrared rather than satellite imagery. While there are many previously discussed benefits to infrared imagery for instructional use, satellite imagery would be more easily obtained for the K-12 classroom and would be equivalent to the technology component of digital globes. If infrared imagery were accessible and cost effective, it would be a valuable asset to the satellite imagery. At minimum, satellite imagery should be acquired to update this curriculum and to possibly accompany infrared imagery for students to be able to compare the two types of data.

Furthermore, the curriculum itself is in need of being updated. The curriculum should contain questions and activities that utilize satellite imagery in lieu of, or in addition to infrared imagery. The existing curriculum is well designed and includes many thought provoking geographical questions. However, with research on spatial thinking skills having been developed since the creation of SC MAPS, it is critical to redevelop the curriculum based on recent research (Gersmehl and Gersmehl 2007, Golledge et al. 2008, and Janelle and Goodchild 2009).
Common Language for Spatial Thinking

Another important area of focus should be to develop a common language for spatial thinking skills. In this study it was difficult to assess exactly what spatial thinking skill was being assessed by a particular question. There were a number of questions that clearly tested more than one skill but were only categorized in one skill area in the STAT. Development of a common language might help to rectify this matter in the future. Additionally, development of a common language will help to further research in the area of spatial thinking as called for by the Roadmap Report (Edelson et al. 2013).

Study Results

While this study focused largely on which instructional media, among other variables, better developed spatial thinking skills among students, it did not focus in depth on which media best teaches specific spatial thinking skill areas. The results of this study show that there is a possibility that different spatial thinking skills are best taught by different media. The eight spatial thinking skill areas used in the STAT should be further investigated by condition to see what practices best help students learn these skills.

The results of this study also revealed that there was a small correlation between past travel experience among students and spatial thinking skill development. Future research should more fully investigate how influential past travel experience is on the development of spatial thinking skills by asking more specific questions about past travel to gain a better understanding of its effects on development.

Additionally, the results of this study showed statistically significant differences between groups based on the interaction effects of race, academic level, and condition. It
would be interesting to further investigate whether students of a particular race and academic level develop better spatial thinking skills by different media.

*Study Design*

Future studies should examine qualitative responses from a larger, more diverse sample size. While both genders, all academic levels, and four different races are represented within the sample size, the study population was only made up of one age group, eighth grade middle school students. Additionally, although four different races were represented, the sample size was limited in some minority races. A study involving multiple age groups as well as including a larger sample of individual races is an opportunity worthy of future research as the socio-economic status of students is not often available for research.

*Student Perception of Personal Map Skills*

A common phrase heard from multiple students during classroom observations and student interviews was, “I’m just not very good at maps.” Future studies should consider why this is such a common statement. It should be investigated to see if this could be an exposure issue; would students not think so poorly of their map comprehension if they were simply more exposed to maps? It would also be interesting to investigate if the digital age has begun to change this notion at all.

*Teacher Preference*

This study focused on the influence of instructional media on student spatial thinking skill acquisition largely by analyzing quantitative statistics. Although participating teachers were interviewed and asked to comment on their preference for instructional media, there was no extensive qualitative analysis performed. Input from
experienced classroom teachers can be very valuable and thus should not go undocumented, but it is also important to consider that many teachers are still Digital Immigrants (Prensky 2001) and thus may have a bias toward paper instruction and possibly against digital instruction. It would be interesting to develop a similar study using a much larger number of teachers to simply investigate whether teachers prefer paper or digital media and the reasons for support of the preferred media. The work of Hurst and Clough (2013) and Pedersen, Farrell, and McPhee (2005) seemed to be heading in this direction by establishing that there is a greater preference for paper maps by both geographic experts and students, respectively. This proposed study should investigate to see if these preferences transfer to the educational classroom. There are certain media, without documented evidence, that teachers know to be successful or unsuccessful based on experience. One example is that paper maps are much more engaging than digital maps. While digital maps are interactive and entertaining, student attention and focus is difficult to maintain when using a computer that offers multiple distractions. Furthermore, usability and network issues often arise during implementation of digital maps in the classroom. This researcher acknowledges and agrees with the work of Meyer et al. (1999) that argue that learning the technology in a K-12 setting often undermines or takes the place of learning about geographical and spatial analysis as both teachers expressed in their interviews that some students initially struggled with operating the Google Earth application. Additionally, Garfield notes that something important has been lost as mapmaking has become “a science of logarithms and apps and precisely calibrated directions” (2012, 1). However, this researcher does not believe that paper maps should take the place of digital maps in the classroom, but rather supplement
them. After all, this society now functions in the digital age and therefore, students must be exposed to these technologies in the classroom. There is simply not a “one-size fits all” approach to teaching spatial thinking. There is reason for their parallel existence, but Hurst and Clough (2013) demonstrate that paper maps are still relevant in the digital age.

This study has sought to determine if spatial thinking skill development differs between analog and digital map use. Beyond different classroom media, it aimed to identify other variables that may affect spatial thinking skill development. The questions asked in this research identify the complexity of spatial thinking and the many possible variables that promote it best. Confirming past research, this study has shown that both paper and digital media aid in developing and improving spatial thinking skill acquisition among students. This study has also shown that despite numerous claims in geography education research, geospatial technology does not necessarily do a better job at promoting spatial thinking than paper maps. In today’s contemporary, digital society there is still a need to utilize traditional paper maps in the classroom, as well as, implementing new geospatial technologies. Spatial thinking is severely underrepresented in the K-12 classroom and both measures should be taken to promote its inclusion. Contrary to past research, other variables such as gender, attitudes towards geography and technology, and access to technology did not have an effect on spatial thinking skill development. This research did show however, that there was a small correlation between past travel experience among students and spatial thinking skill development. These results as a whole suggest that spatial thinking can be improved upon by more exposure to both paper and digital maps, as well as, more travel experience. Spatial thinking is a vast and ubiquitous skill that has multiple pathways to improvement. Geography
educators hold the key to becoming the pioneers in the spatial thinking world as implementation of these skills becomes more focused and present in the K-12 classroom. As one of the participating teachers commented, “We need to be purposeful about including spatial thinking in the classroom, but we can at least start with more exposure in addition to what life in general already provides.”
REFERENCES


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APPENDIX A: TEACHER SURVEY

1. In what discipline is your bachelor’s degree?

2. What is your highest degree earned and in what discipline?

3. How many undergraduate geography courses have you taken?

4. How many graduate geography courses have you taken?

5. Describe/List any additional geography training you have received.

6. How many years have you taught including this year?

7. Have you taught a geography class before? If so, how many years?

8. Describe any use of Google Earth in the classroom.

<table>
<thead>
<tr>
<th>Please circle one response for each item below</th>
<th>1- Not at All</th>
<th>Not at All</th>
<th>Very Little</th>
<th>Somewhat</th>
<th>Very Much</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. How comfortable are you with teaching using maps?</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. How comfortable are you with using technology?</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. How comfortable are you with teaching using technology?</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. How comfortable are you with using Google Earth?</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. How comfortable are you with teaching using Google Earth?</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td>1  2  3  4  5</td>
<td></td>
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</tr>
</tbody>
</table>
APPENDIX B: INFORMED CONSENT FORM

Your child is invited to participate in a research study taking place during regular instructional time in a social studies class. The purpose of this study is to determine whether students learn geography concepts better with paper maps or with computerized technology (i.e. Google Earth). Your child will receive the same content instruction regardless of the method used to teach that content. This study does not interrupt instructional time and hopes to advance learning by investigating the methods best suited for delivering content in the geography classroom.

Student Selection
Your child was selected to participate in this study because your child is an eighth grade student and is enrolled in a social studies course.

Procedure
Your child will complete a short survey based on demographic (age, gender) information, attitudes toward geography, attitudes toward technology, and previous travel experience. Your child will take a short non-graded quiz before the geographic instruction occurs to assess basic geographic knowledge. After completing the lessons, your child will take another short non-graded quiz to assess how well he/she learned the material from the teacher instruction. Students will be invited to share opinions about the activities after the completion of the lessons.

Benefits
This project will benefit student learning generally, and more specifically, provide resources to students and teachers in Lexington/Richland School District Five. Students will receive better geography instruction and teachers will learn the best way in which to deliver this instruction. Teachers and students also will benefit by receiving two free sets of SC MAPS (a $550 value per set) to use and keep in their classrooms.

Risks
The results of the quizzes are not designed for student assessment of material. It is of no harm to the student. The quiz results will not be used to identify individual students and their level of performance. The quizzes are tied to classroom instruction because their purpose is to learn which type of teaching method is most effective and thus most beneficial to student achievement.

Confidentiality
Student information will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study. No reference will be made in oral or written reports that could link your child to the study. No individual identifiers (name)
will be disclosed to anyone and results will only be reported at the group level (gender, age, etc.).

Contact
If you have questions about the study or the procedures or wish to inspect materials before consenting, you may contact Larianne Collins at collin22@email.sc.edu or Dr. Jerry Mitchell at mitchell@sc.edu or 803-777-2986.

Participation and Consent
Your child’s participation in this study is voluntary. **There is no penalty for not participating. Participants may withdraw from the study at any time without penalty. The school district is neither sponsoring nor conducting this research.** If you choose to opt your child out of the study, please sign and return this form to the student’s eighth grade Social Studies teacher by date***.

☐ I do **not** wish (my child) to participate.

Student Name (print) ___________________________________________________

Parent/Guardian Name (print) __________________________________________

Parent/Guardian Signature __________________________ Date _______________
Spatial Thinking Ability Test

(A)

© 2006 Association of American Geographers
Dr. Jongwon Lee, Author
1. If you are located at point 1 and travel north one block, then turn west and travel three blocks, and then turn south and travel two blocks, you will be closest to point.

   (A) 2  
   (B) 3  
   (C) 4  
   (D) 5  
   (E) 6

2. If you are located at point 1 and travel west one block, then turn left and travel three, then turn west and travel one block, and then turn right and travel four blocks, you will be closest to point.

   (A) 2  
   (B) 3  
   (C) 4  
   (D) 5  
   (E) 6
Direction: The map below shows annual precipitation of Texas.

3. If you draw a graph showing change of Texas annual precipitation between A and B, the graph will be ______.
DIRECTIONS: Find the best location for a flood management facility based on the following conditions. First, a possible site for a flood management facility should be within 60 feet of an existing electric line. Second, a possible site for a flood management facility should be located less than 220 feet. And last, a possible site for a flood management facility should be located in State Park or Public Land.

4. Mark √ on the best site (A–E) for the flood management facility on the map above.
5. Imagine that you are standing at location X and looking in the direction of A and B. Among 5 slope profiles (A–E), which profile most closely represents what you would see?
DIRECTIONS: Your job is to find maps that have spatial correlations. For example, map (B) and map (D) have positive correlation (similar patterns).

Example

(A)  

(B)  

(C)  

(D)
6. Find a map (A–F) having a strong positive correlation with the map on the left. (Choose closest one).
Directions: The following two maps show (A) Acres of corn production and (B) Value of hogs and pigs as percent of total market value of agricultural products sold.

7. If you draw a graph showing the relationship between map (A) and (B), the graph will be _______.

(A) \( \frac{\text{acres of corn}}{\text{value of hogs and pigs}} \)

(B) \( \frac{\text{value of hogs and pigs}}{\text{acres of corn}} \)

(C) \( \text{linear relationship} \)

(D) \( \text{curved relationship} \)
8. If you look at the area below in the direction of arrow, which terrain view (A–E) most closely represents what you would see?
DIRECTIONS: Solve the following questions based on the example below. Please mark (√) an answer.

**Example**

- and
- or
- xor
- A not B
- B not A

9.

( ) A and B
( ) A or B
( ) A xor B
( ) A not B
( ) B not A

10.

A or B

A

B

( ) ( ) ( ) ( ) ( )
Solve question 11 and 12 based on the following diagram.

11. (not B) and D

12. A and B and C
Directions: Real world objects can be represented explicitly by point, line (arc), and area (polygon). Based on the examples below, classify the followings spatial data.

Example

13. Locations of weather stations in Washington County ______.
   (A) Lines
   (B) Area
   (C) Points and Lines
   (D) Points and Area

14. Mississippi River channels and their basins ______.
   (A) Lines
   (B) Area
   (C) Points and Lines
   (D) Lines and Area

15. Shuttle bus route of the Lincoln Elementary School ______.
   (A) Points
   (B) Area
   (C) Points and Lines
   (D) Points and Area

16. Places that can be reached by Franklin County fire engines in 5 minutes or less ______.
   (A) Points
   (B) Lines
   (C) Area
   (D) Points and Lines
APPENDIX D: STAT B

Spatial Skills Test

B

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Dr. Jongwon Lee, Author
DIRECTIONS: Answer question on the basis of the street map below.

1. If you are located at point 1 and travel south two blocks, then turn west and travel three blocks, and then turn north and travel one block, you will be closest to point.

   (A) 2  
   (B) 3  
   (C) 4  
   (D) 5  
   (E) 6

2. If you are located at point 1 and travel west one block, then turn left and travel three, then turn west and travel two blocks, and then turn right and travel two blocks, you will be closest to point.

   (A) 2  
   (B) 3  
   (C) 4  
   (D) 5  
   (E) 6
Direction: The map below shows annual precipitation of Texas.

3. If you draw a graph showing change of Texas annual precipitation between A and B, the graph will be ______.
DIRECTIONS: Find the best location for a flood management facility based on the following conditions. First, a possible site for a flood management facility should be within 60 feet of an existing electric line. Second, a possible site for a flood management facility should be located less than 220 feet. And last, a possible site for a flood management facility should be located in State Park or Public Land.

4. Mark ✓ on the best site (A–E) for the flood management facility on the map above.
5. Imagine that you are standing at location X and looking in the direction of A and B. Among 5 slope profiles (A~E), which profile most closely represents what you would see?
DIRECTIONS: Your job is to find maps that have spatial correlations. For example, map (B) and map (D) have positive correlation (similar patterns).

Example
6. Find a map (A-F) having a strong positive correlation with the map on the left. ________ (Choose closest one).
DIRECTIONS: The following two maps show (A) Acres of corn production and (B) Value of hogs and pigs as percent of total market value of agricultural products sold.

7. If you draw a graph showing the relationship between map (A) and (B), the graph will be _______.

(A) [Graph A]  (B) [Graph B]  (C) [Graph C]  (D) [Graph D]
8. If you look at the area below in the direction of arrow, which terrain view (A–E) most closely represents what you would see?
DIRECTIONS: Solve the following questions based on the example below. Please mark (√) an answer.

Example

9. ( ) A and B
   ( ) A or B
   ( ) A xor B
   ( ) A not B
   ( ) B not A

10. A or B
    A
    B

( )
( )
( )
( )
( )
Solve question 11 and 12 based on the following diagram.

11. (not B) and D

12. A and B and C
Directions: Real world objects can be represented explicitly by point, line (arc), and area (polygon). Based on the examples below, classify the following spatial data.

Example

13. Locations of weather stations in Washington County ______.
   (A) Lines
   (B) Area
   (C) Points and Lines
   (D) Points and Area

14. Mississippi River channels and their basins ______.
   (A) Lines
   (B) Area
   (C) Points and Lines
   (D) Lines and Area

15. Shuttle bus route of the Lincoln Elementary School ______.
   (A) Points
   (B) Area
   (C) Points and Lines
   (D) Points and Area

16. Places that can be reached by Franklin County fire engines in 5 minutes or less ______.
   (A) Points
   (B) Lines
   (C) Area
   (D) Points and Lines
APPENDIX E: LESSON 1 – CHARLESTON STUDY SITE

Objective

Students will observe and analyze satellite imagery of Charleston, South Carolina to apply basic map reading skills such as representation of features on a map and direction. Students will compare and contrast the natural and human-made features of the map. Students will also determine the best location for a proposed water ferry into the Charleston Peninsula. Students will critically examine these tasks and thoroughly explain what map clues were used to determine their answers.

Rationale

The Charleston Study Site highlights South Carolina’s most historic port city. For the greater part of the state’s history, politics, commerce, and cultural activity have all revolved around this well known metropolitan hub. Charleston has both prospered and suffered in her role as the Queen City, and later the Holy City. Although formerly known as the “Queen City,” Charleston today is better known as the “Holy City” because of its great number of churches. Several great fires, seven great hurricanes, an earthquake, two occupying armies, and countless boom/bust economic cycles have affected the city since its founding in 1680. Charleston (Charles Towne until 1782) served as the first capital of South Carolina and has always been its primary seaport. It presents an excellent example of the tension that exists between progress, defined as development and industry, and the more picturesque qualities that attract tourists. The conflict is most visible between people who want to preserve the special atmosphere created by the historical areas and those who desire to profit from that historical quality by building restaurants, hotels and other special attractions.

Brief Site Description

The peninsula upon which Charleston was established was originally a low-lying area with a twisting shoreline broken by many creeks and marshes. In its natural state, the peninsula was divided into a number of smaller peninsulas by tidal creeks that penetrated the area. For instance Water Street was, as its name implies, an actual creek until after the Revolutionary War, and the north end of State Street was still planted in rice as late as the middle of the eighteenth century.

However, as Charleston continued to grow, and the demands for space increased, many of the city’s numerous marshes and creeks were filled in. Debris generated by the city’s local industries as well as the wreckage from numerous fires and storms provided a variety of materials for landfill. Large sections of the modern city
occupy land built up through a succession of these reclamation projects. For example, as early as 1717, the city filled in the moat that had been in front of part of the old city wall. Land where the City Market now stands was filled during the early 1800’s. Additional land reclamation operations have expanded the shorelines along both the Ashley and Cooper rivers.

**Early Map of Charleston, 1860**

* Note: The double lines indicate the boundaries of the old city walls.

**The Battery**

At the tip of the Charleston peninsula, where the Ashley and Cooper rivers converge, there was originally a shell beach known as Oyster Point. Eventually, this area became enclosed by the construction of two sea walls and was referred to as the White Point Gardens. The east sea wall was built of ballast rocks carried by trading ships. Ballast rocks were used to weight down the sailing vessels to increase their stability on the high seas. White Point Gardens achieved special notoriety when the infamous pirate Stede Bonnet was executed there. This area acquired the name “the Battery” when cannons were placed there during the War of 1812. During the Civil War, cannons were
again placed along the sea wall, and today a collection of artillery from various periods is permanently displayed in the Park.

**Harbor Dredging and Spoils Areas**

Natural harbors like Charleston are very important to the economy of South Carolina. But as larger and larger ships began to enter Charleston, it became more and more difficult to reach the docks without running aground on sand bars or scraping the bottom in shallow areas. The United States Army Corps of Engineers was given the task of keeping shipping channels open, in Charleston and other coastal cities, by dredging sediment from the designated shipping channels and dumping it on the shoreline. The dredging must be repeated at regular intervals because sediment from the Ashley and Cooper rivers tends to accumulate in these channels. Most of the channels in Charleston Harbor are kept clear to a depth of 35 feet. Channels in the Ashley River and the Intracoastal Waterway seldom exceed a depth of 20 feet. The dumped material is referred to as ‘spoil’. Drum Island, just east of the city in the middle of the Cooper River, is a prime example of a spoil area still in use.

**Charleston Today**

Heritage and tradition have always been important to the people of Charleston. Even though the city endured a long period of economic stagnation from the Civil War until World War II, the people were unwilling to sacrifice their distinctive architectural, cultural, and historic traditions for the promise of a quick profit. When progress threatened this heritage in the 1920’s, the city became the first in the country to pass legislation concerning the preservation of its historic buildings. In 1920, Charleston’s Society for Historic Preservation was born. It not only inspired other preservationist groups around the country to adopt similar laws and ordinances, but it laid the groundwork for the substantial tourism that is so profitable for Charleston today. Since World War II, Charleston has made a remarkable comeback as a seaport, in addition to its continuing role as a home for numerous military installations.

**Basic Map Reading Skills**

What is a map? Maps are means of communication. They are a visual reduction of a reality. ALL maps are distorted because the round Earth cannot be accurately displayed on a flat map. Every map distorts at least one or more of the following: shape, area, distance, or direction. The maps you will be viewing are actually satellite images of a section of Earth. Satellite images are the truest maps we can observe, as they are actual images from Earth’s surface rather than human-made depictions of reality.

In reading a map, always observe the directional indicator, or compass that displays the orientation of the cardinal directions (north, east, south, west). An example is provided below in Figure 1.
Features on a map image can be thought of as representing three types of features: a point, a line, or an area. Every feature on the map is displayed in one of these three manners. Examples are provided below in Figure 2.

**Example**

Ex. trees, road interactions, poles in distribution networks.  
Ex. roads, rivers.  
Ex. the areal extent of a city, an area of a continent.

**Figure 2**
**Activity 1**
Identify Interstate 26 that enters the Charleston peninsula from the north. Identify Highway 17 that runs through the Charleston peninsula in an east-west direction. Are these roads represented on the map by a point, line, or area? (circle your answer)

Point  Line  Area

If you were to leave Battery Park (Point A) and travel to the Citadel Football Stadium (Point B), in which direction would you be traveling? (circle your answer)

North  East  South  West
Northeast  Northwest  Southeast  Southwest

**Activity 2**
First, locate the land area north of Highway 17 on the Charleston Peninsula. Next, locate Interstate 26. Which side of Interstate 26 has the highest building density, West or East? (circle your answer)

West  East

What clues in the map helped you decide?
________________________________________________________________________
________________________________________________________________________

**Activity 3**
Locate the Charleston peninsula. Which parts of the peninsula are more industrial, the Central Part or its Coastlines? (circle your answer)

Central Part  Coastlines

What clues in the map helped you decide?
________________________________________________________________________
________________________________________________________________________
Activity 3 (continued)
Think about the location of the industrial areas you identified in the previous question. Why do you think industry is located in that particular place?


Activity 4
Developed land is land covered or “built up” with buildings and roads.

Is Point C developed land or undeveloped land? Explain your answer.


Is Point D developed land or undeveloped land? Explain your answer.


If you were to travel from Point C to Point D, would you experience an abrupt or gradual change in the look of the landscape? Explain your answer.


Activity 5
Rivers make traveling around Charleston difficult without bridges and ferries. The City of Charleston wants to improve the ability of people who live south of the peninsula to get over to the peninsula. Two places have been proposed to establish a water ferry: from Point E to Point F and Point G to Point A. Would you choose the first route (Point E to Point F) or the second route (Point G to Point A)? (circle your answer).

Point E to Point F    Point G to Point A

What clues in the map helped you decide?


APPENDIX F: LESSON 2 – MYRTLE BEACH SITE

Objective

Students will observe and analyze satellite imagery of Myrtle Beach, South Carolina to apply basic map reading skills such as measurement and direction. Students will compare and contrast physical features on the map. Students will also determine the best location for a proposed cell tower in the Myrtle Beach. Students will critically examine these tasks and thoroughly explain what map clues were used to determine their answers.

Rationale

Travel and tourism has become an increasingly important component of South Carolina’s economy over the last few decades. Tourism contributes both directly and indirectly to the state’s economy. Most tourist dollars are spent on food service and lodging. The remainder generates employment in various service related industries, including transportation, recreation, entertainment, and retail trade. Although beaches have always been attractive to tourists, more and more visitors are looking for additional attractions such as amusement parks, theatres, golf courses, campgrounds, and convention facilities. The Myrtle Beach area has expanded to offer many of these extra features while still maintaining the family atmosphere that continues to draw millions of tourists from both in and out of state. Roughly half of all tourist dollars generated in South Carolina come from the Myrtle Beach area. Many State-Park visits are recorded at Myrtle Beach State Park.

Brief Site Description

Two-hundred years ago, Myrtle Beach was separated from pine forests only by sand dunes, sea oats, scrub oaks, and evergreen myrtle bushes (the origin of the name Myrtle Beach). During George Washington’s tour of South Carolina in 1791, he entered the state on the King’s Highway (now US Highway 17) and visited with many influential and prominent families living in the Myrtle Beach area.

Walking along Long Beach (the name of the Myrtle Beach area in that day) a hundred years ago, you would have seen the large expanse of the Atlantic Ocean to the east. Looking north and south, you would see a long crescent-shaped beach covered with beautiful white sand. For miles inland, you would still see sand dunes covered with picturesque sea oats, scrub oaks, and wax myrtle bushes. Franklin G. Burroughs, a Conway businessman, was the first to see potential for these beaches to become a major
resort area. His company, Burroughs and Collins, acquired a vast amount of timberland which included the beach front all the way from Murrells Inlet to Little River.

About the turn of the twentieth century, his company started a railroad line to transport tourists from Conway to the ocean. Once the railroad opened, the company built its first resort hotel, the Sea Side Inn. The company later sponsored a contest to select the name for its new resort. A popular suggestion was “Edgewater”; however, the name “Myrtle Beach” won the contest mainly because of the abundance of the evergreen aromatic plant called wax myrtle (Myricaceae cerifera) growing along the Long Beach area.

Myrtle Beach Today

Currently the area is crowded with tourists and their vehicles, heading to and from the many golf courses, hotels, motels, condominiums, specialty shops, and restaurants that have developed along the Grand Strand, as the area is called today. However, more serious problems than traffic jams or over-development threaten the future of the tourist industry at Myrtle Beach. Seasonal hurricanes and beach erosion have become major concerns. Since the late 1970’s, when the city first began to study the problem, it has been determined that the ocean encroaches the shoreline at Myrtle Beach by approximately a foot per year due to normal erosion (not including additional damage caused by storms). To combat this problem, South Carolina has carried out several expensive beach renourishment projects where more sand was added to beaches and dunes. These projects do not halt beach erosion but do slow the effects. Beach erosion will continue to present a threat to coastal development and tourism and will also continue to generate public debate on the best way to maintain and protect coastal development.

Basic Map Reading Skills

What is a map? Maps are means of communication. They are a visual reduction of a reality. ALL maps are distorted because the round Earth cannot be accurately displayed on a flat map. Every map distorts at least one or more of the following: shape, area, distance, or direction. The maps you will be viewing are actually satellite images of a section of Earth. Satellite images are the truest maps we can observe, as they are actual images from Earth’s surface rather than human-made depictions of reality.

In reading a map, always observe the directional indicator, or compass that displays the orientation of the cardinal directions (north, east, south, west). An example is provided below in Figure 1.
Features on a map image can be thought of as representing three types of features: a point, a line, or an area. Every feature on the map is displayed in one of these three manners. Examples are provided below in Figure 2.

**Example**

- **Point**: trees, road interactions, poles in distribution networks.
- **Line**: roads, rivers.
- **Area**: the areal extent of a city, an area of a continent.

**Figure 2**
Activity 1
Identify the Myrtle Beach airport. Locate the runway. Measure its length from Point A to Point B. Approximately how many feet is the runway? (circle your answer)

8,500 feet  9,500 feet  10,500 feet

If you were located at Point 1 and travel northeast one block, then turn southeast and travel two blocks, and then turn northeast and travel three blocks, at which point would you be closest? (circle your answer)

1  2  3  4  5

Activity 2
Identify the Myrtle Beach Pier that is adjacent to the grid from the previous question. Draw a line from the end of the pier out into the ocean. Make sure that your line is one mile in length and perpendicular to the coast. Note: one mile = 5,280 feet. Notice that the color of the water changes along your line. Is the change Gradual or Abrupt? (circle your answer)

Gradual    Abrupt

Why do you think the color of the water changes?

________________________________________________________________________

________________________________________________________________________

Activity 3
Locate the Myrtle Beach airport. What is the major orientation (direction) of the airport, North-South or East-West? (circle your answer)

North-South    East-West

Why do you think the airport is oriented in that direction as opposed to another direction?

________________________________________________________________________

________________________________________________________________________
Activity 4
Locate the Intracoastal Waterway. If you are located at Point 6 in a sailboat headed southwest, when looking directly ahead in what direction does the Intracoastal Waterway go? (circle your answer)

- It bends right towards the east
- It bends left towards the west

- It bends left towards the east
- It bends right towards the west

Activity 5
You have been challenged with locating a cell-phone tower for a new international cell-phone company. There are four criteria that must be followed to determine the best location for this cell tower. First, it must be on vacant land that is not already developed. Second, it must be located south of the Intracoastal Waterway to be closest to the largest number of users. Third, it must be located at least half of a mile directly inland from the Atlantic Ocean to avoid flooding from coastal storms. Lastly, it must be no closer than 1 mile from the Myrtle Beach airport runway to avoid air traffic. Note: one mile = 5,280 feet. Which point on the map is the best location for the new cell tower? (circle your answer).

7 8 9 10

Explain your choice and why the other three sites were unacceptable.
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
APPENDIX G: TEACHER INSTRUCTIONS

Lesson 1: Teacher Instructions

1. Explain to the students that they are going to perform several activities using a map of Charleston, South Carolina. Explain to them that these activities will require them to think spatially about the map.

2. Have students read the introductory material aloud (popcorn format) on the Charleston study site. This information will give them background knowledge on the study site itself.

3. After reading the “Basic Map Reading Skills” section, ask students if there are any questions about this information.

4. SC MAPS – Organize students into groups of 2. (If there is an odd number of students in the class, one group may have 3 members.)
   - GE – Organize students into groups of 2 per computer. (If there is an odd number of students in the class, one group may have 3 members.)

5. SC MAPS – Distribute one map of Charleston to each group.
   - GE – Open GE on the desktop. Make sure ALL features are turned off in GE except the “Chas” kmz. file. Have students use the mouse to scroll slightly in or out on the zoom bar, then press “R” on the keyboard. Pressing “R” will display the image orthogonally. Instruct the students to repeat this function anytime they need to get back to the original image. Explain to the students that the only part of the Charleston area that is included in the lesson appears in the big red box. All answers will be based on this area.

6. Distribute the Lesson 1 Worksheet to each student. Make sure that the pre-coded number goes to the same student that was given that number for STAT A.

7. There are 5 activities for students to complete. Allow the students to work on each activity for several minutes and instruct them to stop before moving onto the next activity. After completion of each activity the various answers will be discussed as a class. Make sure to engage students in discussion of each activity and have them answer why they chose the answers they chose.

Activity 1 Answers – Line: Make sure students understand the definition of a peninsula. Ask students how they identified Interstate 26 and Highway 17. Technically, on this imagery, the answer could be area. However, on a map roads are generally represented by lines.

Northwest: Ask students how they came up with their answer. Ask them if the directional indicator always points north. Ask them if the answer would change if the directional indicator on the map was not pointing north.
Activity 2 Answers – West; Answers may vary, but clues should be that the number of buildings on the west are more numerous than the ones on the east. Make sure that students understand the definition of the word density.

Activity 3 Answers – Coastlines; Answers may vary, but clues should be that there are many large building that seem to be warehouses along the coastlines, whereas the buildings in the central part of the peninsula are much smaller and seem to be more residential; Answers may vary, but industry is primarily located along the coastlines for access to water for shipping and along the key transportation routes.

Activity 4 Answers – Developed; Answers may vary, but developed land should be denoted by buildings and roads. Undeveloped; Answers may vary, but undeveloped land should be denoted by lack of buildings and roads. Abrupt; Answers may vary, but it should be noted that the developed land stops abruptly where the marsh begins.

Activity 5 Answers – Point G to Point A; Answers will vary but clues should state that even though Points E and F are closer together and thus a shorter distance, there is no infrastructure near the location of Point E. In addition, there are large residential areas near Point G (and existing infrastructure) that have no quick route onto the peninsula. Therefore, Point G to Point A is more logical for the new ferry route.

Lesson 2: Teacher Instructions

1. Explain to the students that they are going to perform several activities using a map of Myrtle Beach, South Carolina. Explain to them that these activities will require them to think spatially about the map.
2. Have students read the introductory material aloud (popcorn format) on the Myrtle Beach study site. This information will give them background knowledge on the study site itself.
3. After reading the “Basic Map Reading Skills” section, ask students if there are any questions about this information.
4. SC MAPS –Organize students into groups of 2. (If there is an odd number of students in the class, one group may have 3 members.)
   GE – Organize students into groups of 2 per computer. (If there is an odd number of students in the class, one group may have 3 members.)
5. SC MAPS – Distribute one map of Myrtle Beach to each group.
   GE – Open GE on the desktop. Make sure ALL features are turned off in GE except the “MB2” kmz. file. Have students use the mouse to scroll slightly in or out on the zoom bar, then press “R” on the keyboard. Pressing “R” will display the image orthogonally. Instruct the students to repeat this function anytime they need to get back to the original image. Explain to the students that the only part of the Myrtle Beach area that is included in the lesson appears in the big red box. All answers will be based on this area.
6. Distribute the Lesson 1 Worksheet to each student. Make sure that the pre-coded number goes to the same student that was given that number for STAT A.
7. There are 5 activities for students to complete. Allow the students to work on each activity for several minutes and instruct them to stop before moving onto the next activity. After completion of each activity the various answers will be discussed as a class. Make sure to engage students in discussion of each activity and have them answer why they chose the answers they chose.

**Activity 1 Answers** – 9,500 feet: On the SC MAP, students will need to use the map scale to answer the question. On GE, students will need to use the ruler feature to answer the question. Allow students time to figure this out on there own, but be sure that they do eventually realize what tool to use to properly answer the question. You may prompt them with questions such as “What would you need to properly answer this question?” (a ruler) and “What do you see on the map that might help you complete this task?” (a map scale/ruler). 5: Students will have to use the directional indicator to answer this question. Make sure students remember that they must remain in the labeled neighborhood grid to follow the instructions and obtain the correct answer.

**Activity 2 Answers** – Gradual; Answers may vary, but possible answers would include that the lighter water is more shallow, while the darker water is deeper. Students may also describe the sediment load in variation of water color; the lighter areas have more sediment build up while the darker areas have less sediment build up. Students will have to use the map scale to answer this question with SC MAPS and use the ruler feature on GE.

**Activity 3 Answers** – North-South; Answers may vary, but possible answers could include that the runway is placed in accordance to prevailing wind patterns or that the area of land was available at the time of the creation of the airport. Students will need to use the directional indicator to answer this question.

**Activity 4 Answers** – It bends to the right toward the west. This question requires the student to use the directional indicator and to think about being situated in the waterway itself.

**Activity 5 Answers** – 9; Answers will vary but should state that 9 is the only choice location that meets all four of the required criteria. Point 7 cannot be used as it is north of the Intracoastal Waterway; Point 8 cannot be used as it is located less than one half mile inland from the Atlantic Ocean; Point 10 cannot be used as it is located less than one mile from the Myrtle Beach airport runway.
# APPENDIX H: STUDENT SURVEY

Please Circle Once Response for each item below

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1. I enjoy learning about people and places.</td>
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</tr>
<tr>
<td>2. I enjoy learning about the environment (rivers, weather, trees etc.).</td>
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<tr>
<td>3. I enjoy looking at maps and globes.</td>
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<tr>
<td>4. Maps and globes are easy for me to use.</td>
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<tr>
<td>5. I enjoy using computers.</td>
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<tr>
<td>6. Computers are easy for me to use.</td>
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<tr>
<td>7. I have easy access to computers outside of school.</td>
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<tr>
<td>8. I have easy access to the Internet outside of school.</td>
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<tr>
<td>9. A job that uses maps would be exciting.</td>
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<tr>
<td>10. I would like to study geography in college to help me get a job.</td>
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</tr>
<tr>
<td>11. Have you ever traveled outside South Carolina?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t Know</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Have one or both of your parents ever traveled outside South Carolina?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t Know</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Have you ever traveled outside the United States?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t Know</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Has one or both of your parents ever traveled outside the United States?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t Know</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>