

## ABSTRACT

BRANCH, BENJAMIN DEWAYNE. A Study of Educators' Perceptions of Spatial Thinking. (Under the direction of Dr. Paul Bitting and Kenneth H. Brinson, Jnr.)

The purpose of this dissertation study was to explore perceptions of policy makers and educators towards spatial thinking. Following the issuance of Executive Order 12906, Coordinating Geographical Data Acquisition and Access: The National Spatial Data Infrastructure, by the federal government in 1994, educators have become interested in exploring their possible roles in spatial thinking, broadly defined as the use of space to define, formulate and solve problems.

This work was a qualitative study that relied on interview data from educators and policy makers who have some knowledge and/or experience with spatial thinking. From the interviews, four themes emerged: public interest, administrative capacity, classroom use and policy and research. Suggestions are offered for enhancing the role of spatial thinking in each of these areas.

A Study of Educators' Perceptions of Spatial Thinking

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## **DEDICATION**

It is with great pleasure that I acknowledge God for His involvement in my life and my development for the present and the future. With God on my side, and with my psyche in humble obedience, I believe that all things are possible.

To my beautiful and courageous wife, Mrs. Jamillah Scott-Branch, from whom I have learned to fight on in spite of incredible odds. I thank you and love you so much for your support.

To my son and daughter, Ulon and Urie Branch who passed on May 26, 2006, and whose spirit lives in me and within my household. To my older son, Benjamin Dewayne Adedapo Branch Jr., you are motivation! To my youngest son, Jabien Malik Branch, whose smile and laugh fuels my passion, we have legacy to build.

To my parents, Mr. and Mrs. Benjamin F. Branch, thanks for praying me through my journey. I still hear Grandma Sadie and Grandma Lola calling on God for a way out of no way.

## **BIOGRAPHY**

Benjamin Dewayne Branch, Jr., was born in the southeast part of Washington, DC, and blessed with the support of wonderful parents, Mr. and Mrs. Benjamin F. Branch. Education was a vital focus of my rearing. Their support propelled me from my graduation from W. G. Enloe High School, Raleigh, NC, to receiving two degrees from North Carolina Agricultural and Technical State University, Greensboro, NC. These degrees include a Bachelor of Science in Industrial Engineering and a Masters in Computer Science. Ten years of professional experience includes positions at Lockheed Martin Federal Systems, IBM, and MCI/WorldCom. In academics, I have been a technology teacher in middle school and a Pre-Awards Specialist at Saint Augustine's College, Raleigh, North Carolina.

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## CHAPTER 1

### Introduction

The purpose of this dissertation study was to explore perceptions of policy makers and educators towards spatial thinking concepts. It did so using grounded theory, as defined by Creswell (1998) and Charmaz (2006). An instrument was developed and used to conduct interviews, along the lines suggested by Seidman (2006). The data analysis included various types of coding that led to an interpretation that produced a set of findings. Specifically, findings indicated that the themes of public interest, administrative capacity, classroom use, and policy and research are aspects of educational change that should be considered.

### Statement of the Problem

The relevance of spatial thinking as an issue in educational policy has greatly increased in recent years as a result of actions taken by federal and state governments. At the federal level, the issuance of Executive Order 12906, Coordinating Geographical Data Acquisition and Access: The National Spatial Data Infrastructure (Federal Geographic Data Committee, 1994; The White House, 1994), has required government agencies to manage data in a spatially aware manner. Corresponding actions have also been taken by the states.

The North Carolina legislature created the Geographical Information Coordination Council (GICC) to coordinate the spatial data infrastructure of all state agencies via Senate Bill 895 in August of 2001, which is incorporated in the General Statutes §143-725 through 143-727 (North Carolina Geographic Information Coordinating Council 2003, 2006, 2008). In the course of its work, the GICC has made

ample use of geographical information systems (GIS) as referenced by General Assembly of North Carolina (2003) and the North Carolina Geographic Information Coordinating Council (2003, 2006, and 2008). GIS involves the use of global positioning satellites (GPS) (Longley, Goodchild, Maquire, & Rhind, 2005). Moreover, the legislation that established the GICC specifically mandates that the State Superintendent of Public Instruction, the elected leader of elementary and secondary education in North Carolina, participate as a member of the GICC. This plainly suggests that spatial thinking will be an important skill for those aspiring to top-level leadership roles within the state's elementary and secondary school systems. Yet the extent to which practicing educators currently are equipped for such roles is uncertain. As will be discussed in later sections of this work, leaders sometimes delegate this responsibility to members of their staffs.

More generally, a series of questions arise from these policy developments concerning the present and future role of spatial thinking in public education. Before considering such questions, however, it will be useful to specify exactly what is meant by the concept of spatial thinking. As used in this dissertation, spatial thinking refers to the use of space to describe, formulate, and solve problems, as well as to teach and conduct research. And as described by the National Academy of Sciences (2006, p. 36), "the basis for spatial thinking is the structure of space and the operations that we can perform on that structure".

### Research Question

In order to achieve these goals this study sought to examine a key research question: What aspects of educational change do participants believe must occur in order for a GIS/spatial thinking culture to reach widespread implementation? All levels of educational professionals who support GIS policy or applications in education may be considered potential study participants.

### Theoretical Framework

The theoretical framework for this study was influenced heavily by the works of John Dewey. Values of Dewey, such as open-mindedness, intentional learning, and education renewal were applied in a modern context as devices to generate evidence that may be applicable to theory and practice in ways that contribute to meaningful educational change.

Indeed, Dewey identified communication as an important societal need: "The essential need, in other words, is the improvement of the methods and conditions of debate, discussion, and persuasion. That is the problem of the public" (Dewey, 1939/1991, p. 208). This study suggests that spatial thinking and its tools such as GIS/global positioning satellites (GPS) may be a significant improvement in the methods and conditions of debate, discussion, and persuasion. "Effective use of data will change a school's culture" (Sorenson and Goldsmith, 2006, p. 53). Dewey (1993) stated that, along with consulting the public for input, the solution to communicating with the public

includes issues of natural sciences. For instance, the skilled use of a map, which is a very simple spatial tool, may be a means for government to enhance communication concerning the public interest.

Hare (2004, p. 2), a specialist in foundational studies, stated that “the world, as Dewey saw it, was strikingly characterized by fundamental change of every kind with far-reaching consequences for education... Dewey’s view was that ‘since changes are going on anyway, the great thing is to learn enough about them so that we may be able to lay hold of them and turn them in the direction of our desires’ ” (Dewey, 1920/1982: 146). Therefore, “education, Dewey believes, must aim at preventing opinions being held and asserted dogmatically (1912/1979:292), and open-mindedness is the crucial virtue here” (Dewey 1912 and 1972, as cited in Hare, 2004, p. 4). Modern education may borrow from Dewey (1912) such a rationale for educational change in the form of a spatial thinking culture.

In addition, foundational studies may aid the educational renewal of qualifications for citizenship in a world that is faced with spatial dilemmas such as global warming, a global economy, and globally competitive education. From *Experience and Nature*, Dewey (1925) stated the following:

There are two avenues of approach to the goal of philosophy. We may begin with experience in gross, experience in its primary and crude forms [e.g., traits]. . . . Or, we may begin with refined selective products, the most authentic statements

of commended methods of science [e.g., maps], and work from them back to the primary facts of life (p. 2).

Maps use geography where a decision may result. Dewey (1916) stated, “To ‘learn geography’ is to gain in power to perceive the spatial, the natural connections of an ordinary act” (p. 210). In other words, spatial data may be rendered in a map for decision-making. Hence, a geographical information system is just a data driven form of making maps for decision-making.

In 1994, the United States government chose GIS as a tool in its data infrastructure and the Fifty States Initiatives is a policy movement for all fifty states to comply. “The Fifty States Initiative is a partnership between the National States Geographic Information Council (NSGIC) and the Federal Geographic Data Committee (FGDC). It is designed to bring all public and private stakeholders together in statewide GIS coordination bodies that help to form effective partnerships and lasting relationships” (National States Geographic Information Council, 2009). Likewise, North Carolina has complied in 2002 with its GICC, while other North Carolina policies such as the 1997 Leandro article 2 (North Carolina Administrative Office of the Courts, 1997), mention geography as part of a child’s right to a sound basic education.

Thus, in simple terms, as Dewey used maps as a valid decision model, the federal government uses maps for decision-making where GIS is an essential tool that has been mandated for all fifty states. Educational leaders may agree that (McClune 1986 as cited

in Short, Short, and Brinson, 1998, p. 5), “Strategic planning involves studying changes in the larger society and the way those changes may impact the school organization”. Thus, it is logical for educators to deem spatial thinking useful at all levels of education as a means of addressing spatial issues in society (National Academy of Sciences, 2006). Likewise, educators of the future may have to plan and strategize mechanisms to provide and sustain a globally competitive education. The use of using data-based decision making tools may play an important role (Short, Short, and Brinson, 1998).

### Significance

At this point, educational leadership and policy studies as a profession may not be generally aware that GIS could be an essential tool whose use is increasing in the information systems of society and government. Likewise, GIS would manage data that has characteristics represented in terms of space, from which its stakeholders would formulate data into attributes of geography, specifically, a map. A simple analogy connected spatial thinking and GIS in the following way: spatial thinking is to GIS as breathing is to a lung. In other words, GIS is the best means for conducting spatial thinking, as a lung is the best means for breathing. A spatial thinking culture could be emerging as the growing numbers of education professionals partake in spatial thinking or GIS practice in classrooms, educational research settings, or when making policy.

In common terms, GIS is a database that has the ability to capture attributes of geography to measure such issues as distance or area and indicate a model of the problem

scenarios with possible solutions in a data-driven manner. Spatial thinking and the use of GIS are an educational renewal option for the discipline of geography. Hence, the terms spatial and geography may be considered interchangeable.

Other researchers, including Allen (1999b), have referenced a continuation of Dewey's (1916) notion that time and space are key influences on educational experience, suggesting that education in general has not formally optimized the importance of space in terms of its educational potential. Allen (1999b, p. 4) and others have argued that the concept of space is a vital consideration for social scientists stated "that space is an irreducible, essential quality of humanness and social being" (Lefebvre, 1991; Foucault and Miskowiec, 1986; Soja, 1989, 1996).

Widespread use of spatial thinking models, such as those described by Legates (2005), might not occur due to barriers in a spatial thinking culture in education, such as a lack of spatial literacy. White (2005) stated that such areas need attention. Nevertheless, how can this attention be valued if present educational leadership is not aware of the potential of spatial thinking or GIS in education or the power of data-driven activity?

Finally, the social contract between educational leadership and the public may arguably center on helping students to prepare to be productive citizens. Such a commitment resonates in efforts to incorporate 21<sup>st</sup> century skills within the student experience. Central to the argument of this work is that before the student experience can credibly reflect 21<sup>st</sup> learning, the leaders of the educational system must themselves



possess sufficient knowledge and awareness to direct, evaluate and access instruction in spatial thinking related paradigms.

### Organization of Study

The goal of this study was to investigate the conditions that could facilitate the implementation of spatial thinking throughout education. The study was conducted using the method of grounded theory. Chapter 1 has provided an overview and context for spatial thinking as a consideration of educational change. The literature review in Chapter 2 illustrates applicable theories and literature that support a need for such a study. Chapter 3 details the methodology and discusses procedural aspects of this study. Chapter 4 discusses research findings. Chapter 5 discusses the conclusions and implications for theory, practice, and future research.

## CHAPTER 2

### Literature Review

In general, Deweyan centered values, such as open-mindedness, intentional learning, and educational renewal are used to frame a rationale for educational change in combination with federal and state policy realities. Specifically, Dewey's (1925) use of maps as a decision making tool is linked to the reality of federal policy, Executive Order 12906, Coordinating Geographical Data Acquisition and Access: The National Spatial Data Infrastructure (Federal Geographic Data Committee, 1994) and North Carolina's response to such policy that utilizes data in a means where it is collected, analyzed and presented in the context of a map.

Here, philosophy is essential to educational leadership and policy studies consideration in terms of serving the public interest. In addition, visionary philosophy and practice of education will aid, predict, and define the direction and capacity to lead. "The first thing educational leaders do when they lead is reach for their philosophy" Brinson (2005, lecture notes).

Open-mindedness, a means to reach collective agreement or feedback from stakeholders or public interest (Bitting, 2003), proves as a vital concept as education wrestles with issues of a global economy, climate change, and producing future citizens capable of negotiating their social identity in a complex world. Intentional learning, as described by Oblinger and Oblinger (2005) indicated that future education will require a

higher form of thinking. Educational renewal can be considered most easily since educational leadership has had a tradition of managing its data from a library of information as implied by Short, Short, and Brinson (1998). Here, educational renewal is a practical consideration as the North Carolina Geographical Information Coordinating Council (GICC) could be essentially building a digital library capable of supporting all state agencies, including the State Department of Public Instruction.

As such, this work proposed that before spatial thinking and geographical information systems (GIS)/global positioning satellites (GPS) could be conveyed and implemented properly in the K-12 experience, the educational practices must be in place to address such implications and potential. In addition, as local and state governments further prepare, manage, and embrace GIS in their data operations Onsrud, Johnson, and Winnecki (1996) and; General Assembly of North Carolina (2003), public education may have to do likewise.

In *Democracy and Education*, (Dewey, 1916 as cited in Garrison, 2003) stated, “a technical definition of education: It is that reconstruction or reorganization of experience which adds to the meaning of experience and which increases the ability to direct the course of subsequent experience” (p. 3). In this research effort, the policy congruencies between spatial thinking and present educational policy should promote awareness of spatial thinking and GIS use as a reconstruction of present and future experience.

Reality exists where entities who prepare future educator have not prepared historically or exposed their clientele to experiences of decision-making capacity that GIS could relate to educational strategic planning, bus logistics, community orientated learning, 1997 Leandro, article 2 compliance, or NSF grant opportunities that require a GIS skill set. In the case of North Carolina's GICC, this example supports the notion that superintendents' knowledge of GICC compliance and use of GIS warrants further debate and discussion among its profession.

Short, Short, and Brinson (1998) stated, "New ways of storing and accessing data make it possible to use information in all types of decision making activities". Furthermore, a lack of awareness of spatial thinking in society and its evidenced based policy status may suggest a need for more educational change. McClune's 1986 work (as cited in Short, Short, and Brinson, 1998) stated "Strategic planning involves studying changes in the larger society and the way those changes may impact the school organization" (p. 5).

Open-mindedness is a key virtue expressed by Dewey (1897) in his philosophy of education. Hare (2004, p. 17) stated, "An open-minded individual is willing to allow his or her beliefs to become unsettled in order to entertain new possibilities, to set preferred conclusions aside in order to follow the evidence, and to revise beliefs so as to reflect the evidential support". Hare (2004, p. 17) further stated that "open-mindedness helps us to cope with, and respond to, an unsettled world by suggesting to us new ways of addressing

emerging issues and new insights into familiar problems, thus keeping us committed to reaching whatever settled ground we can”.

Moreover, Hare (2004, p. 2), a specialist in foundational studies stated, “that world, as Dewey saw it, was strikingly characterized by fundamental change of every kind with far-reaching consequences for education”. Moreover, Dewey (1897) stated, “New inventions, new machines, new methods of transportation and intercourse are making over the whole scene of action year by year. It is an absolute impossibility to educate the child for any fixed station in life” (Dewey, 1897 and 1972, p. 59). Thus, even in Dewey’s era, a need for educational change was a common reality where education for students’ benefit should change as influenced by technology innovation in society. Dewey, 1912 and 1972 works (as cited in Hare 2004, p. 36) as “Education, Dewey believes, must aim at preventing opinions being held and asserted dogmatically (1912 and 1979, p. 292), and open-mindedness is the crucial virtue here”.

Philosophically, Dewey (1912) provided a construct of open-mindedness as a means to consider geography or maps as valid to their decision-making process. Such examples are further discussed in Chapter 2. From *Experience and Nature*, Dewey (1929, p. 2) stated the following:

There are two avenues of approach to the goal of philosophy. We may begin with experience in gross, experience in its primary and crude forms [e.g., traits]. . . . Or, we may begin with refined selective products, the most authentic statements

of commended methods of science [e.g., maps], and work from them back to the primary facts of life.

One avenue is through experience and the other was through tools, which in this case Garrison (2005, p. 2) implied are maps. A map, as a tool, conveys meaning through the concept of space. Dewey (1916) distinguishes space from geography whereby geography was space that has a social value or meaning. Thus, as discussed, GIS collects, analyzes, and models features of space/geography, which might have a social value to the researcher or other stakeholders. Here, the terms spatial thinking, mapping (the use of maps or geography), geospatial, and geographical information systems are interchangeable. In addition, the terms educational change, renewal, and reform are interchangeable. Moreover, this study's use of the term GIS includes the use of global positioning satellites (GPS) technology, which can be considered a medium or tool that conducts and generates the data collection into GIS and such databases.

Dewey (1925) utilized maps in his lifetime to convey meaning in terms of space. This activity precedes even the National Academy of Sciences' (2006) reference to Bruner (1958, p. 237) using the concept of space in the classroom for teaching purposes. This is significant because it directly links to Allen's (1999a) notion of map making or cartography being a viable representation of space. "Human existence can be readily expressed and understood through the cartographical or topographical 'mapping' of what are understood to be 'concrete' geographies" (Allen, 1999a, p.13). In addition, this

suggested that Dewey may have influenced Bruner's work as it certainly pre-dates his activity.

Dewey (1916) clearly acknowledged that student experience was dependent on factors such as time and space. Dewey (1916) stated, "As a societies[sic] become more complex in structure and resources, the need of formal or intentional teaching and learning increases" (p. 9). Allen (1999b, p. 3) stated that "Dewey believed that all schools, whether traditional or progressive, are essentially about experiences that lead to growth". All aspects of education should consider their own experiences as being correlated to issues of time and space because a major Science Technology Engineering and Mathematics (STEM) policy actor, such as the National Academy of Sciences, has done so. "Therefore we need to invest in a systematic educational program to foster spatial literacy by enhancing levels of spatial thinking in K-12 students" (National Academy of Sciences, 2006, p. 22). Such activity by a major policy maker like the National Academy of Sciences (2006) may influence educational change.

A Dewey (1916) perspective indicated intentional learning increases as society grows more complex, which was echoed by the work of Oblinger and Oblinger (2005). If spatial problems such as climate change or water shortage take up the agenda, education may need to respond through intentional learning to address public interest. Moreover, if the educational arena becomes more intertwined with GIS use in bus transportation,

school reassignment, or school redistricting, then spatial thinking is a valid intentional learning activity for more applications in education.

It is suggested that an intentional learner has an intense problem solving capacity. Such contemporary thought expressed by Oblinger and Oblinger (2005, p. 93) stated,

Becoming such an intentional learner means developing self-awareness about the reason to study, the learning process itself and how education is used. Intentional learners are integrative thinkers who can see connections in seemingly disparate information and draw on a wide range of knowledge to make decisions. They adapt the skills learned in one situation to new problems encountered in another- in a classroom, the workplace, their communities, and their personal lives.

This can be a characteristic required in future 21<sup>st</sup> century learning. Hence, 21<sup>st</sup> century educational leadership can promote such influence with such intentionally set in the mindset of its profession.

Dewey (1916) stated that education consists of a self-renewing process. A spatial thinking culture may be an opportunity for educational change that could empower the education community to reinvent its role in society. Likewise, a definition of planning was given as, “Planning: the process of looking into the future, identifying resources and needs, and creating a master plan to follow” (Thompson and Wood, 2005, p. 106).

Dewey (1916) advocated that the central focus of education was to give the student the ability to think. Such a skill transfer may be difficult by educational



administration in terms of compliance to the integration technology requirements of NCLB. Thus, education will have to include the means to ensure that spatial thinking grows in supporting workforce needs.

In other words, GIS should be considered comprehensively to model certain aspects of reality and mimic its function in order to simulate possible solutions or scenarios. Philosophically, Jean Piaget indirectly validated the use of GIS or spatial thinking in education. “As Piaget succinctly put it, ‘the essential functions of intelligence consist in understanding and in inventing, in other words in building up structures by structuring reality’ ” (Garrison, 2003, p. 3). Piaget’s words inferred that modeling reality may be a valid means of creating structures in which relationships of activities and participants can be evaluated intelligently. Such is a capability of data driven models. Hence, this integration of technology opportunity is a practical experience consideration for the decision-making toolset of educational administration.

Kerski (2003, p. 134) stated, “case studies showed that one of the chief constraints on GIS learning is not hardware or software, but the spatial perspective of teachers and students. Most students lacked this spatial perspective and were uncomfortable with the problem-solving style of learning of which GIS takes advantage”. In addition, Kerski (2003, p. 134) noted a teacher preparation challenge for GIS as “Although the computer lab manager’s involvement was found to be critical, overall computer issues were secondary to the time required to create and maintain lessons and data, structure of the

school day, school politics, and spatial thinking. Winkle (1998, p. 1) stated, “Demands for GIS education and training are now being met by a loose combination of workshops, short courses, college and university instruction, and GIS degree programs”.

“Dewey retained his historical focus as he surveyed how issues of geography, time, technology, and magnitude had influenced the emergence of publics and states” (Asen, 2003, p. 7). Certainly, if geography or spatial thinking were that vital in the development of publics and states, it could play an essential role in transforming the K-12 experience as Kerski (2000) advocated.

“Dewey saw experience as inseparable from time and space” (Allen, 1999b, p. 4). Likewise, the educational researcher's experience, in particular, such as school district management issues, may benefit from the same perception. Dewey (1916, p. 210) stated, “To ‘learn geography’ is to gain in power to perceive the spatial, the natural connections of an ordinary act”.

Oblinger and Oblinger (2005) deemed intentional learning as increasing the exchange of ideas in society. (Dede, Whitehouse and Brown-L’Bahy, 2002 as cited in Oblinger and Oblinger, 2005) further stated, “As a result, intentional learners succeed even when instability is the only constant”.

Short, Short, and Brinson (1998) noted a traditional relationship between educational leadership and its data, termed as a library experience. They advocated the use of data-driven decision models. Thus, data-driven models can be considered an

inherent activity in spatial thinking or GIS use. In simple terms, the database use advocated by Short, Short, and Brinson (1998) was similar to this dissertation's advocating GIS training for present use. GIS in pure technical terms could be considered a database that can measure attributes of geography such as distance and area. In an educational arena, this could involve tabulating optimal distances of bus routes to estimate or calculate gas costs or annual school budget funding based on the physical area of a school district.

DeMille (2006, p. 63) stated, "All generations before this one have had geographical frontiers to conquer". Hence, spatial thinking may assist to conquer day-to-day dilemmas of bus routes, school planning, and other logistics that generate a cost or benefit. Purely, the ability of educational professionals to think in this mode and secure professional relations is a practical frontier.

Automated, complex data collection, analysis, and presentation are practical forms of experience needed by educational administration before they can evaluate it properly in the classroom experience. Johnson (2004, p. 269) stated, "... if policymakers and practitioners make teaching a rewarding career that sustains teachers over time, the schools, themselves, will inevitably change for the better to the benefit of both students and the public".

*Contemporary spatial thinking considerations or indicators*

In addition, specific examples of spatial thinking in considerations are discussed, along with current indicators of spatial thinking in education. With specific uses of spatial thinking or GIS in education, major studies of GIS in education are discussed which included the works of Kerski (2000), White (2005) and Hagevik (2003) and the National Academy of Sciences (2006), along with some North Carolina policy and federal policy.

Table 2.1

Current indicators of a spatial thinking culture

<b>Current Indicators</b>	<b>Type of educational professional</b>	<b>Implications of educational change</b>
Alibrandi and Palmer-Moloney (2001)	Middle school specialists/educators	Spatial literacy for these professionals
Kerski (2000)	High school specialists. Educators	Spatial literacy for these professionals
National Academy of Science (2006)	Educational researchers	Policy change that brings congruence with K-12 needs and college educational skill development in spatial thinking
Dewey (1916 and 1897)	Specialist in foundational studies	Specialists in foundational studies may have the best philosophical reasoning for a spatial thinking culture and may be the best spatial thinking policy advocates

It should be noted that a substantial effort is needed to move spatial thinking and GIS use into the K-12 classroom. Unfortunately, such may only be conceivable by spatially literate, aware, or proficient educational professionals. Likewise, researchers Alibrandi, Hagevik, and White (2002) support such pedagogical development in public middle schools. Kerski (2000) advocated teaching GIS in high schools. At the primary or elementary school level, Everett (2000) noted that Jean Piaget was renown for his contribution to spatial thinking in his works *The Child's Conception of Space* (1948) and *The Child's Conception of Geometry* (1960). "The theory and stages attributed to the work of Piaget and Inhelder were the foundational pieces that would lead to further investigation of how individuals would process and externalize the spatial representations in their minds" (White, 2005, p. 86).

Taylor, Vasu, and Causby (1999) established GIS in education planning for school districts on the issue of school redistricting in Johnston County, NC. From such work, it is be implied the influential role of GIS associated research activity at North Carolina State University, especially in terms of educational research capacity through the College of Education's researchers at the Institute for Transportation Research and Education (ITRE) program. Specifically the problem statement in the study of Taylor, Vasu and Causby (1999) stated that GIS use has aided superintendent rates in North Carolina as a decision-making tool and providing accountability. Moreover, the ITRE program has served the local educational agencies (LEAs) in North Carolina using GIS in

some form. Kerski (2000, p. 4) stated, “GIS analysis has been a critical part of land-based decisions made daily by academic, business, and government organizations for over 20 years”.

Stubbs, Devine, and Hagevik (2000) advocated the need for educators to think spatially in K-16 education settings. In addition, they even included *A Five-step Plan and Methodology to Introduce GIS to Educators State-wide* plan for North Carolina that focused on science education. Other sources indicate the following:

Spatial thinking is *not* an add-on to an already crowded school curriculum, but rather a missing link across that curriculum. Integration and infusion of spatial thinking can help to achieve existing curricular objectives. Spatial thinking is another lever to enable students to achieve a deeper and more insightful understanding of subjects across the curriculum (National Academy of Sciences, 2006, p. 26).

Here, the culture of education requires open-mindedness for the implications of a spatial thinking culture.

In addition, a research effort known as MentorNet at North Carolina State University considered GIS to be an innovative instructional technology documented in a research-1 category of higher education review by the National Council for Accreditation of Teacher Education (NCATE). If GIS can make its way into an organization’s NCATE review, then certainly it has the validity to evolve into formal use by education.

Researchers such as Dr. David Uttal and Dr. Gersmehl may be most adept at leading the way in the area of spatial cognition. Specifically, this work acknowledges a work entitled, “Spatial Thinking by Young Children: Neurologic Evidence for Early Development and ‘Educability’ (Gersmehl & Gersmehl, 2007), as connecting groundbreaking premises into brain research which may yield insight from a spatial learning experience valuable to spatial learning model constructs. A spatial learning model may result in having GIS intentionally used by educational leadership and research and may already be in use informally by STEM disciplines. NCLB should allow experimentation, research, and consultation with federal agencies engaged in heavy spatial thinking activities.

GIS could become a standard part of many public school systems’ toolsets. For example, the Wake County Public School System in North Carolina formally utilized GIS in school reassignment efforts, using very complex data. Wake County Public School System’s GIS department has existed for approximately 15 years. Mecklenburg and Cumberland counties' school systems in North Carolina formally utilize GIS also. In addition, as a traditional educational researcher and policy analyst, Cobb (1999 and 2003) has documented the value of using GIS in a research study. The North Carolina Department of Public Instruction has utilized GIS to create maps that display information for decision-making and comprehension.

The issuance of Executive Order 12906, Coordinating Geographical Data Acquisition and Access: The National Spatial Data Infrastructure (Federal Geographic Data Committee, 1994) act passed by the Clinton Administration is the root of spatial thinking from a policy standpoint, because it requires all federal agencies to standardize their operational data in GIS formats. Its vision is that “current and accurate geospatial data will be readily available to contribute locally, nationally, and globally to economic growth, environmental quality, stability and social progress” (Federal Geographic Data Committee, 1997).

Legitimate rationale for educational professionals is influenced by the support of government agencies through the GICC mandate because, “...educational innovations tend to gain legitimacy and acceptance on the basis of social evaluations, as the endorsements of legislatures or professional agencies” (Rowan, 1982, p. 3). For example, the National Center of Educational Statistics (NCES) has a GIS-based online School District Demographics System, for national use. Carl Schmitt, a NCES statistician stated, “NCES has utilized GIS for several years” (C. Schmitt, personal communication, November 27, 2006).

In simple terms, the North Carolina 2002 GICC is the state's effort to comply with policy known as the 1994 Spatial Data Infrastructure Act that was passed during the Clinton Administration. Here, all federal agencies are required to collaborate and standardize operation data in a GIS format. The United States Department of Education



is a federal agency that has to comply with this mandate. State implications exist nationally, and state agencies may have to respond to such policy implications.

Thus, the National Academy of Sciences (2006) advocated, “Our goal must be to foster a generation of students (1) who have the habit of mind of thinking spatially, (2) who can practice spatial thinking in an informed way, and (3) who adopt a critical stance to spatial thinking” (p. 3-4). It could be true that education must be able to respond to the societal influence of a major STEM discipline policy actor who promotes spatial thinking at all levels of education. Specific government indicators from the President’s High Growth Job Training Initiative in 2005 from the United States Department of Labor (2005, p. 4) are as follows:

There is a lack of public awareness of the impact of geospatial technology applications on daily professional and personal activities. With greater understanding will come greater interest in entering the profession, as well as greater demand for geospatial capabilities and applications across a wide range of other sectors. The Geospatial Information & Technology Association (GITA) reports that approximately 70 to 80 percent of the information managed by business is somehow connected to a specific location—an address, street, intersection, or ‘xy’ coordinate .

Furthermore, other United States Department of Labor (2005, p. 5) indicators such a geospatial gap in the workforce that is not be addressed by educational leadership as follows:

The fastest emerging occupations within the geospatial technology industry require technical skills, yet the industry does not have enough training models or curricula to develop the necessary pipeline of skilled workers, creating significant gaps between workforce supply and demand. These gaps will likely grow unless there is a coordinated effort at the national level to study the issues, develop solutions, and implement them throughout the workforce.

Moreover, it is be an essential job function of educational leadership to recognize job trends in society, as well as, maximize its ability to plan strategically, sustain, and renew the data-driven aspects of their job function. As such, this communication issue has to involve the management of data and its presentation to stakeholders. “While increased accountability is just one part of NCLB, all schools must gather data and overcome barriers to analyzing and using the data” (Bernhardt, 2004, p. 125).

Specifically, leadership has to influence teachers' professional development and student learning in terms of spatial thinking which may be defined as the STEM discipline geosciences. A data-driven process is essential even where school data could be effectively assessed and evaluated. A democratic educational system requires technology integration, as indicated in NCLB section 2112.

#### *Congruent Research Studies*

(Phoenix, 1999 and GeoPlace, 1999 as cited in Kerski, 2000), “GIS has become a \$5 billion business worldwide (Phoenix 1999) and has been growing by over 10%

annually for the past decade. Over 500,000 people worldwide use GIS software” (Phoenix 1999, p. 4). Kerski (2000, p. 4) further stated, “The GIS industry encompasses software and hardware developers, research, sales, data producers and consumers, consultants, professional societies, journals, user groups, and conferences”. This may prove significant because funded research could be vital to the progression of educational professionals in terms of highlighting expertise.

Furthermore, efforts by United States Department of Labor, 1991, Hill, 1995, Jacobs, 1989, Furner and Ramirez, 1999 and Sarnoff, 2000 (as cited in Kerski’s 2000, p. 4-5) indicated, external factors are obvious drivers of the spatial movement in education as the following:

The United States Labor Secretary's Commission on Achieving Necessary Skills (SCANS) stated that the most effective way to teach skills is in the context of an established subject matter (United States Department of Labor 1991). The SCANS competencies include identifying and using resources, working with others, acquiring and using information, and understanding complex interrelationships (Hill 1995a and 1995b). Interdisciplinary education, rather than teaching each subject in isolation from the others, may be a more effective means to help students solve problems (Jacobs 1989). Implementing GIS into the curriculum may encourage students to examine data from a variety of fields (Furner and Ramirez 1999; Sarnoff 2000).

Kerski (2000, p. 108) said,

Innovation research suggests that “change agents”—in this case, teachers using GIS—must concentrate their energies on the opinion leaders in the social system to enhance the possibility of adopting innovations. The lack of administrative support will therefore continue to make the pace of GIS implementation sluggish.

In addition, Kerski (2000, p. 27) stated, “...that GIS implementation cannot be effective without reform, and that reform can be expedited by GIS implementation. Technology is a key component of reform” (Plotnick, 1995 and Trotter, 1997 as cited in Kerski, 2000, p.1) stated, “Educational technology is perceived as a major vehicle in the movement toward education reform”. A major rationale for a spatial thinking culture may have been provided by (Scott, 1999 as cited in Kerski, 2000, p.1) as “Workers will be increasingly expected to demonstrate knowledge and skills that will make them successful in the information age”.

Kerski (2000) was instrumental in establishing GIS in education considerations for spatial thinking in the classroom. Such work was utilized in works by Alibrandi, Hagevik and White (2001) supporting GIS in the classroom and teacher development.

Hagevik (2003) provided a simple definition: “Spatial thinking can be defined as the ability to see your world in your mind, to manipulate it and to explore it” (p. 23). As GIS may be fundamental to advancing concepts of spatial literacy, proponents of this spatial movement may believe such as Hagevik (2003, p. 23) stated, “This "new" way of

thinking and learning from a spatial-visual approach is seldom addressed in instruction” .  
“Complex scientific relationships and principles can be more effectively communicated and understood through the use of visual images rather than with text alone” (Hagevik 2003, p. 23).

Havegik (2003) cited Dewey’s contribution to inquiry based learning as work that argued for GIS in the science education experience. Hagevik (2003, p. 33) stated,

Efforts to engage students in inquiry-based instruction date back to John Dewey (1938). Dewey believed that children learn by doing through extended experiences that involve discussions and real-world problem solving activities”.

Perhaps, school leadership can champion GIS use for teachers. White (2005) stated that such areas need attention. Nevertheless, how can such attention be valued if educational leadership were not aware of the potential of spatial thinking or GIS in education? White (2005, p. 84) stated, “One aspect of mapping and spatial behavior not given attention by educators is the role of the biological and neurobiological aspects of the human brain in spatial cognition”.

White (2005) conveyed GIS in the classroom from a curriculum instruction perspective. Hence, future spatial thinking leadership may exist because it may be plausible for teachers to become principals or serve in other educational roles.

An indirect support of a spatial thinking is communicated in *An Evaluation of Four Place-Based Education Programs* by Powers (2004) where GIS was an integral

research tool. “The whole school improvement model tends to tackle sustainability and stability issues better by gaining buy-in from multiple stakeholders from the beginnings and thereby providing teachers [and the public] with a broader, longer term base of support” (Powers, 2004, p. 20). This is a validation of Bitting’s (2003) continuation of open-mindedness where the view of many stakeholders paints a complete portrait of understanding for the group of stakeholders.

“We need to invest in a systematic educational program to enhance levels of spatial thinking in K–12 students” (National Academy of Sciences, 2006, p. 11). Education professionals should not ignore this bold call for educational change by a major policy maker like the National Academy of Sciences (2006), whose research reputation is second only to Nobel Prize researchers.

The National Academy of Sciences (2006, p. 3-4) advocated, “Our goal must be to foster a generation of students (1) who have the habit of mind of thinking spatially, (2) who can practice spatial thinking in an informed way, and (3) who adopt a critical stance to spatial thinking”. The Academy (2006) also advocated spatial literacy for student learning. This dissertation suggests that educational professionals should be spatially literate and have a formal set of standards before they attempt to use or teach this in the classroom. Thus, educational professionals are not be able to promote spatial literacy effectively to students if they themselves are not spatially literate.

The 1997 Leandro article 2 (North Carolina Administrative Office of the Courts, 1997) indicated that geography was a part of sound basic education where a student can think about their socioeconomic status on local, state, or national levels. In this work, the terms space, geography, geo-spatial and spatial are synonymous where geography simply adds a social connection or meaning to space.

Certainly, a growing spatial culture in education exists, which seeks acceptance, reform, and policy consideration for greater spatial literacy and implementation in education. Legates (2005, p. 2) stated,

A small number of faculty in each of the social science disciplines and public policy fields have sufficiently mastered GIS concepts and operations to use GIS effectively in their own research and are able to incorporate GIS into their teaching.

#### *Research Question Development*

Thus, the research question was polished until its final form: What aspects of educational change do participants believe must occur in order for a GIS/spatial thinking culture to reach widespread implementation? All levels of education professionals who support GIS policy or applications in education are considered valid participants in this study.

In simplest terms, the ability and awareness via open-mindedness, intentional learning, and educational renewal education may aid spatial thinking or GIS in advancing

such an experience for of educational administration. A Deweyan influence requires a re-visitation for open-mindedness, intentional learning, and educational renewal as a means to increase their compliance and awareness to such federal and policy. If the society and the government on a federal and state level would be use spatial thinking and adhere to such policy, leadership should follow suit. The question that remains would be, does this mean that educational administration should be spatially literate, proficient, or both?

At odds in this discussion is the issue of educational change from either a systemic or incremental effort in relationship to advancing spatial thinking in K-12 or higher education venues. As the National Academy of Sciences (2006) called for systemic change, this study asked a cross-section of the population of this spatial thinking culture to get their responses as to where systemic or incremental change was practical. Other factors assume that the effective use of data will change a school's culture (Bernhardt, 2004). A spatial thinking culture would advocate the data to be used with spatial characteristics involving GIS.

#### Summary and Conclusions

Both dissertation studies by White (2005) and Hagevik (2003) link GIS to Dewey in some aspect. However, such works did not provide a Deweyan rationale applied to a spatial thinking culture. Collectively, White (2005), Hagevik (2003), Kerski (2000 and 2003), Alibrandi (2003), Alibrandi, Hagevik & White (2002) and Alibrandi & Palmer-Moloney, (2001) fit into a GIS in Education category where they advocate for GIS in the



curriculum or science educators' tool set and noted its lack of full scale implementation. In addition, efforts by Davis & Hyun (2005), Audet and Ludwig (2000), and Audet (1993) are other works in this category. Thus, this work attempted to develop a GIS Policy in Education category. For example, the GIS in Education genre utilized Kerski (2000) to state that there were no mandates for GIS in the curriculum. This work cited the GICC as a 2001 mandated coordination for GIS in North Carolina in terms of the state infrastructure. However, Kerski's (2000) assertion still holds true in 2009 where Virginia may be on track to set a precedent. As the National Academy of Sciences (2006) advocated spatial applications being available to students, this study seeks first to ensure that educational professionals are proficient enough in GIS to conduct tasks that require it.

Moreover, White (2005) and Hagevik (2003) addressed spatial thinking in terms of its relationship to brain research and learning theories. In addition, this study noted the importance of educational leadership's role in such educational change.

White (2005) used Roger's (2003) diffusion of innovations theory to explain the expansion of GIS in education. This work took a different approach by considering actual dissemination policy as an evidenced-based rationale for change.

Furthermore, this study places GIS in a policy context where educational change was likely to occur in combination with systemic education reform as indicated by the National Academy of Sciences (2006). Cobb (2003) suggested that education researchers

and policy analysts should be involved formally in the spatial thinking. Overall, this study generated a theory of educational change in terms of spatial thinking or GIS use.

The essence of Chapter 2 displays gaps in literature that show that this dissertation study should be considered a valuable contribution the body of scholarly knowledge. In this case, linkage to a core set of foundational studies of Dewey (1987, 1916, 1925, 1939, and 1991) discussed his influence. Discussions included current indicators, policies, and aspects of a spatial thinking culture.

## CHAPTER 3

### Methodology

#### Introduction

The chapter describes the sample of study participants, along with the means by which they were selected. Also discussed are issues in data collection and data analysis of this grounded theory research effort.

#### Sample

The data was generated from a set of interviews with study participants, who consisted of policy makers and educators with the knowledge and interest to advance spatial thinking and GIS/GPS in education. A pre-qualifying questionnaire was sent to qualify each potential interviewee as a knowledgeable proponent of the spatial thinking activity or geographical information systems (GIS) implementation. The function of the survey was as an icebreaker and clarification medium to potential interviewees about the purpose of this research. These potential interviewees were initially identified through their participation in national and international conferences or in the North Carolina Geographical Information Coordinating Council (GICC). The intention was to select members and others who could contribute to this theory and lead to other study participants via word of mouth. Ultimately, the study participants were chosen on the basis of their knowledge and interest in spatial thinking. Twenty-eight interviews were conducted; of these, twenty-four were digitally recorded and transcribed while four were

conducted through email. The members of the sample are listed anonymously in Table 3.1, along with brief descriptions of their professional roles.

Table 3.1

Study participants in this dissertation: Confidential format

<b>Dissertation Participants</b>	<b>Notable Characteristics</b>	<b>Geographical Locations/University</b>
Study participant 1	GIS professional	Alabama
Study participant 2	Department of Public Instruction (NC's K-12 education system), NC GICC member	Raleigh, NC
Study participant 3	Geography/GIS	University of Southern California
Study participant 4	Advanced spatial thinking in K-12	Virginia
Study participant 5	Urban planner	San Francisco State University
Study participant 6	>(45 years of experience) GIS is K-12	Detroit, MI (school system)
Study participant 7	GIS instructor	Tennessee State University
Study participant 8	PhD student. GIS Instructional Designer	Oregon
Study participant 9	> 20 years exp	Educator- Science education, NSF grant principal investigator
Study participant 10	15 years experience (3D modeling expert)	Southern University and A & M College, Professor, GIS
Study participant 11	Assistant Principal	Johnston County, NC
Study participant 12	Researchers, Education, transportation, consulted for educational planning by a school district	North Carolina State University

Table 3.1 continued

Study participant 13	GIS in Education and Forestry, former NC GICC member	University of Tennessee
Study participant 14	> 30 years exp, NC GICC member, state expert	NCSU, Natural Resources Expert
Study participant 15	Water & environmental policy, NC GICC member	Duke University
Study participant 16	Policy analyst, NC GICC subcommittee member	NC League of Municipalities
Study participant 17	> 20 years exp	Founder of GIS program at major university in California
Study participant 18	> 20 years exp, written books	Professor- Geography, University of California, Santa Barbara, NSF grant in GIS
Study participant 19	Retired teacher > 20 years	Virginia
Study participant 20	NASA	Maryland
Study participant 21	PhD student	West Virginia
Study participant 22	Earth Science researcher	California, researcher
Study participant 23	Librarian	NCSU
Study participant 24	> 20 years exp	Educational Director of major GIS firm
Study participant 25	\$30 million in spatial research, consulted for educational planning by a school district	University of North Carolina, NSF grant awardee GIS/Researcher
Study participant 27	20 > Years	GIS Education expert
Study participant 27	Teacher training	Brazil, teacher
Study participant 28	Psychology	Northwestern University

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## Data Collection

### *Instrumentation/(Interview questions)*

The Appendix displays the instrument that was developed from the literature review and preliminary fact-finding activities. The information was collected during recorded interviews that were transcribed and analyzed.

The range of dates for interviews are recorded in each actual interview as they are discussed. The range began after the IRB approval date in May 2006. The bulk of interviews was conducted from June 1, 2006 until September 15, 2006. A set of final interviews was conducted in the months of October 2006 to November 2006. Follow-up interviews was offered in the fall of 2006 in the month of December.

Table 3.2

#### Interview characteristics

Type	#
In person	8
Telephone	16
Email	4
Length of time characteristics	
Minutes	
Shortest	25
Longest	110
Average	50

In addition to those listed in Table 3.1, several individuals with interest in spatial thinking were approached but were unable or unwilling to participate in this study.

Two sets of follow-up sessions occurred from November 3 through December 20, 2007. All participants were offered follow-up sessions in an effort to have three interviews on the same set of questions. These follow-up sessions were IRB approved in October 2007. The set of first round interviews were in-depth, which may explained the lack of follow-up sessions. Data saturation occurred from the data collected during the initial interviews. A transcription service was utilized. Some of the data recording had low-volume sections where in some words were inaudible. However, this had a negligible impact on data because some questions did repeat in the interviews. In addition, the audio could be replayed and latter clarified.

#### *Linkage of Research Questions to Interview Questions*

The main research question of this dissertation was the following: What aspects of educational change must occur in order for a GIS/spatial thinking culture to reach widespread implementation?

This question became the basis for the series of nine questions posed to participant during each interview. The interviewing protocol questions sought to saturate all angles of the research questions. Thus, the answers of the nine interview questions should map to robust answers to a central research question. In essence, the nine-protocol questions act as topical questions, where topical questions “cover the anticipated needs for information” (Creswell, 1998, p. 101). Stake’s 1995 study (as cited in Creswell, 1998) stated, “issue subquestions address the major concerns and perplexities

to be resolved” (p. 101). The strategy of using subquestions is to generate thinking and in-depth response for the main questions under consideration. The list of questions and a brief statement of their role played by each in this study follows:

- 1) What type of educational researcher/policy [study] participant are you? Are you an educator, educational researcher, policy maker, future educational grant applicant, grant funding agency personnel, or other?

This question frames the concept of open-mindedness where many perspectives unite to project a single rationale. Bitting's (2003) concept of open-mindedness was considered here. The term "study participant" is for an individual who engaged in an activity where future policy considerations could be formulated. This was a topical subquestion.

- 2) What is your experience with GIS/spatial thinking? How did you get interested in this approach? How do you think a spatial movement could better serve the student experience in K-12 education or researcher experience and why is that?

The questions were asked in order to determine if a spatial thinking experience exists and what state it may be in educational practice. In addition, the way the study participants became aware and engaged in spatial thinking activity might suggest such is repeatable in educational policy that favors problem-based learning in the standard course of study.

The prospects of spatial thinking and its potential needs might require open-mindedness. This was an issue subquestion.



- 3) What influence do you see as being the primary driver of GIS policy in education? How do you see a spatial thinking culture involved in the future of education and policy development? What ways of thinking do you perceive are enhanced by GIS applications at various levels of education?

Here, study participants had the opportunity to suggest what they perceive as a primary driver in education for a spatial thinking culture. A policy entrepreneur could gain insight in terms of angles and considerations for possible solutions that might benefit the public interest. Here, ways of thinking were indicated by study participants. This was an issue subquestion.

- 4) Are rubrics and standards needed for student experience and teacher professional development? What connections between school and community do you think can be enhanced by GIS activity?

This subquestion was used to see if any standards for spatial thinking existed that might lead to a standard course of study. If so, teacher professional development could be an issue. The connection issue is to see the potential of spatial thinking in the educational experience in terms of community relations.

- 5) How do you perceive GIS as gaining acceptance in policy and classroom use?

This question focused on gauging the spatial thinking status in policy and classroom use. This was an issue subquestion.

- 6) What aspects of educational change must occur in order for a GIS spatial thinking policy to emerge?

This question was to provide a policy entrepreneur with a glimpse at potential rationale that could propel a spatial thinking agenda in education. This was an issue subquestion.

- 7) Do you think a spatial thinking movement can only emerge from a vast reorganization and reconstruction of educational policy?

This question was to gauge whether study participants favor incremental change or systemic change as referenced by the National Academy of Science (2006). This was an issue subquestion.

- 8) What was your biggest issue of resistance to spatial thinking paradigms of GIS as an educational professional? Do you see a need for all educational professionals to be spatially literate or GIS proficient? Why or why not? What kind of change did it present for you?

This focus tried to identify obstacles or ways to bring more awareness of the spatial thinking culture in education. The issue of spatial literacy and GIS proficiency are used to form a pattern. In addition, a change in thinking was the target of the last question in this section. This was a topical subquestion.

- 9) What types of reform do you think are best for a spatial thinking culture? What role does communication of data play in this consideration?

This question was to gauge whether study participants favor incremental change or, like the National Academy of Sciences (2006), suggest systemic change. The issue of data in the educational process was used to see what possible considerations might emerge. This was an issue subquestion.

### Reliability/Validity

In qualitative research, validity can be established by employing a sound interview protocol, in which specific subquestions are used to elicit participants' perceptions about topics pertaining to the major research questions. More precisely, Creswell (1998) recommends the following steps: eliciting responses from multiple individuals around a central phenomenon, locating a sample that is homogenous with respect to their knowledge of the topic, conducting primary interviews with 20-30 persons, following a standard interviewing protocol, observing standard interviewing practices, and transcribing interview content. As Creswell indicated, the participants need to have experience with the main issue, which, in this case, is spatial thinking in education, policy, or research. According to Creswell (1998, p. 118), "the investigator chooses participants based on their ability to contribute to an evolving theory." In addition, the research design was simple and should be easily re-duplicated for future research.

As a benchmark of interview protocol, the North Carolina State University Institutional Review Board (IRB) approved this protocol. Here, consent forms were used to confirm study participants' involvement.

Research reliability dealt with the concern that the data was believable and realistic. Moreover, the Dewey linkage favored a pragmatic interpretation instead of rhetorical interpretation. In addition, the study participants were asked the same questions. A conditional matrix or visual representation of a possible theory was generated from the axial coding phase that should mirror the findings in some fashion. The challenge here was that the participants represented different communities. In addition, all study participants had the opportunity to follow up on all comments. All in person and telephone interviews were recorded and transcribed. The email interviews did not need to be transcribed. Creswell (1998) stated that grounded theory reliability is enhanced by the use of a minimum of 20 interviewed participants. "Interviews play a central role in the data collection in a grounded theory study" (Creswell, 1998, p. 122). The questions asked were open-ended.

The North Carolina State University Institutional Review Board (IRB) approval was granted on June 15, 2007. All IRB approval process steps were in place before any interviews took place, for both primary and follow-up efforts. The most critical skill in interviewing was listening and getting the participants to be themselves. Discussions to gain insight were attempted in some cases when there was need for explanations.

## Data Analysis

The data was coded in six random groups of study participants. The categories were derived through repeated analysis until the most important reference terms emerged to form a category.

Email interviews were copied and put into a rich text format. All data transcriptions were put into rich text format. The recorded interviews were transcribed and then that data was used in the grounded theory activities such as open coding, selective coding, and axial coding. The digital data was stored on a secure personal computer and email account. The transcribed data was also stored in the same manner.

Research criteria were developed and utilized to explain the goals of this grounded theory approach or framework. Creswell (1998) stated such criteria are evidence of ensuring reliability in research results. The following criteria were utilized in the analysis of the research data:

- 1) A pattern was sought in the research data among participants.
- 2) To handle bias, issues of contrast were sought in collected data between the participants to ensure that all aspects of the issue were taken into account. Both pros and cons were discussed.
- 3) A central phenomenon or main theme in data was sought as a starting point to generate a theory.

- 4) An array of implications was then derived from the central phenomenon to suggest possible solutions and future implications.

This work uses the procedure of theoretical sampling which involved the qualifying of sample participants. The primary tool in this effort was the pre-qualifying survey. Such was based on participant knowledge and interest. Charmaz (2006) and Creswell (1998) noted this method is a necessary step in defining sample members. Charmaz (2006) stated, “The purpose of theoretical sampling is to obtain data to help you [the researcher] explicate your categories”.

Major criteria were utilized to manage and ensure unbiased discussion about how the samples were coded and collected and on what grounds; what major categories emerged; what were the major indicators of the categories; and on what basis of the categories that the theoretical sampling proceeded. These grounded theory criteria were referenced by Creswell (1998) as normal practice. Such categories found in the data were labeled with the following terms: geography, data, problem solving, and influence.

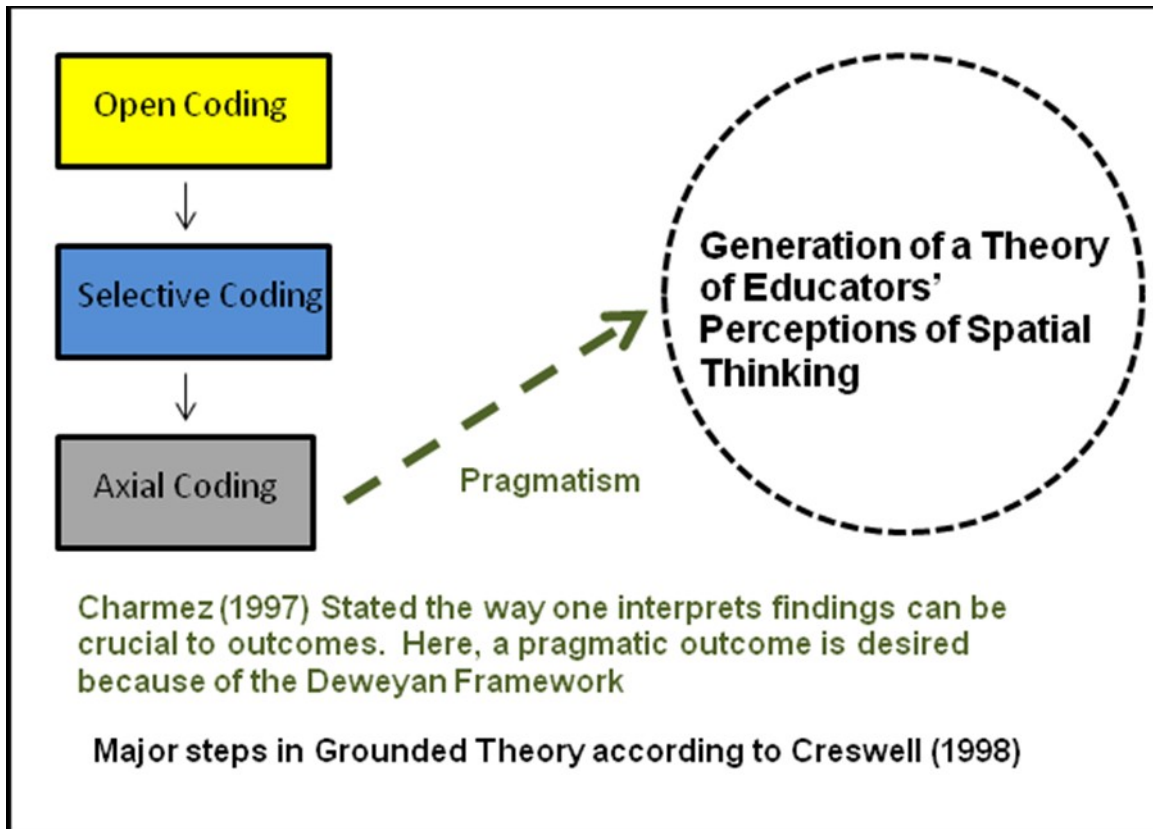
#### Grounded Theory Guidelines

The purpose of grounded theory research is to generate a theory of from the perceptions of the study participants. For purposes of this dissertation, “Grounded theory is defined as a theory generated from data systematically obtained and analyzed through the constant comparative method” (Conrad 1978 as cited in Creswell, 1998, p. 101).

Charmaz (2006) stated that a key ingredient in grounded theory is the collection of rich data.

Lastly, the interview protocol compliance and data transcription issues are discussed in this section. Charmaz (2006) stated “Interpretative theory calls for the imaginative understanding of the studied phenomenon”. Because of the Dewey theoretical framework, a rhetorical solution is not sought but rather a pragmatic one.

Major criteria framed how the sample was collected and on what grounds, what major categories emerged, the major indicators of the categories, and the basis of the categories that the sampling indicated.



*Figure 3.1. Analysis Steps*

Data analysis results were produced by common laptop software such as Microsoft Excel, in combination with the transcription data. The initial phase of the transcription coding looked for aspects of the initial categories and attempted to form a consensus from the data.

Results were not analyzed by Atlas Ti because it was not necessary as “The findings are the theory itself” (May, 1996, as cited in Creswell, 1998, p. 179). Therefore,



to search for a series of words as a pattern is not essential to grounded theory. Figure 3.1 gives an overall view of the coding phases that began with open coding. In addition, the selective coding and axial coding provided different roles, as discussed, in analysis of the data that paints a picture of data results. Major themes of the results were described and research moved to the next phase after data saturation and review.

### *Open coding*

Goals of open coding activity are represented in an open coding diagram where initial expectations are set from literature review for an initial schema where broad categories are generated as guides for later theory development. The coding categories consisted of philosophical and modern influences, current indicators, and ways education can renew itself in a spatial thinking culture. These categories provided an initial framework for analysis. The open coding utilized a comparative approach, which attempts to saturate the categories. The coding was repeated until the category depth was saturated. After a single category produced a central phenomenon-namely, that some type of change is warranted, subsequent effort centered on better defining the details of this educational change.



*Figure 3.2.* Categories of initial open coding schema

From these initial categories in Figure 3.2, other categories evolved that included geography, data, and problem solving. These categories were added for axial coding and selective coding efforts. Such are an important aspect of the constant comparative method as referenced by Creswell (1998) because they help to center the research interpretation. Please note that synonyms were used in the case of data and information. Geography was considered a fundamental aspect of spatial thinking.

### *Selective Coding*

Selective coding is the process of “building a ‘story’ ...” (Creswell, 1998, p. 150). Its purpose is to build the stories that emerge from the data within generated categories. In selective coding, the main goal is to “take the central phenomenon and relate it to the categories” (Creswell, 1998, p. 242). The building of stories emerged from repeated main themes collected and from any consensus that participants reached.

The selective coding involved pulling themes or concrete concepts from the data that made a certain point that was either for or against a spatial thinking culture. This process began with a raw data set of 249 pages. Through selective coding experience, a data reduction of non-connected points from the raw data produced a collection that was approximately 75 pages. Such data reduction was expected, and leads to the next type of coding which is referred to as axial coding.

### *Axial coding*

Axial coding is a process of connecting the stories generated from selective coding. The axial coding utilized the themes generated from the selective coding phase. The axial coding diagram indicated a presence of spatial thinking in education and suggested change derived from the participant interviews.

After coding efforts are completed, their influence on the interpretation of the material was the final phase of the data analysis. A pragmatic type of interpretation was deemed necessary to be consistent with the theoretical framework of Dewey. What was learned from the data is the essential premise. The actions of “doing the interviews, studying the transcripts, marking and labeling them, crafting profiles, and organizing categories of excerpts” are intricate endeavors that determined the interpretation of the material and conclusions (Seidman, 2006, p, 110).

### *Safeguards Against Researcher Bias*

The grasping of the various perspectives on how to advance spatial thinking aided the study to avoid bias by ensuring open-mindedness. Bitting’s (2003) concept of open-mindedness is used here to seek broad considerations for educational change. Hare (2003, p. 7) stated, “Paul Bitting advances the idea that cross-cultural understanding, grasping the perspective of another person, results from the kind of open-mindedness that involves seeing another person’s world ‘as it is’, and this is a form of aesthetic awareness”.

## CHAPTER 4

### Results

Chapter 4 discusses the findings for the research question, what aspects of educational change must occur in order for a GIS/spatial thinking culture to reach widespread implementation?

The major findings were generated from the dialogue of the study participants. The major themes of leadership in the public interest, administrative capacity, classroom use, and awareness of policy and research provided the framework in the review of findings. The leadership in the public interest theme provided broad examples of why the public interest may benefit from considerations of spatial thinking by educational leadership. The administrative capacity theme was generated and centered on attempting to indicate job capacity where spatial thinking was or could be utilized in their present or future job functions. Third, a classroom use theme surfaced from discussions of how spatial thinking could support teacher efforts to promote student learning. Fourth, a policy and research theme emerged that centered on a geography or GIS justification.

#### Public interest

The public interest theme began with discussion of North Carolina's Geographical Information Coordination Council. Study participant 2 and study participant 12 gave especially good insight. Study participant 2 provided some clarifications of the purpose of GICC in North Carolina:

The activities in GIS of the state agencies and their counterparts in the federal government and local government are to be done to the extent they can be coordinated through this government committee. So it's not requiring agencies to use GIS. But it's requiring GIS programs within agencies to have a linkage back to this council (study participant 2, interview, August 31, 2007).

Educational change, in general, and spatial thinking in particular, may be restricted by some policy inherent in NCLB. For example, study participant 2 (interview, August 31, 2007) stated,

We have very limited exposure to spatial reasoning and spatial analytic in teacher preparation. This carries over as the teachers become administrators. So it's limited. There's also significant financial burdens which I think have disappeared now. But the problem is that teachers are motivated by their curriculum and their curriculum doesn't include spatial reasoning. So it's a vicious cycle. If I say your school's going to be evaluated on how kids do at end of the year tests, and end of the year tests don't develop spatial reasoning because people haven't thought about that, then you're never going to make any progress.

Such higher priority placed on testing outcomes overshadows the concept of spatial thinking as an instructional tool.

The ability of educational leadership to have data, use it properly, and communicate its value to the public interest was considered paramount. For example,

study participant 2 (interview, August 31, 2007) stated, “One of the powerful things about GIS is that it gives you visualization capabilities and the ability to generate new hypotheses that you probably wouldn’t do.”

Spatial thinking was linked to survival skills of society and this was indicated by study participant 14 (interview, August 27, 2007). Here, educational change was promoted mostly in practice where issues of public concern include water shortage, school reassignment, or school transportation. Study participant 14 (interview, August 27, 2007) stated the following:

There has to be some understanding at the administrative level that this is a base skill for survival and that students that can’t integrate information at a spatial temporal context are going to be severely disadvantaged in all aspects of their productive capability.

Similarly, study participant 2 (interview, August 21, 2007) referenced that GIS was an essential part of the North Carolina Department of Public Instruction’s Transportation Division for 25 years in both practice and public policy.

Yet, spatial thinking skills or GIS/GPS tool use has not crossed over into the K-12 standard course of study despite respondents’ sense that its potential value is already reflected in world events and in schools’ administrative functions.

Also noted was the following:

If you look at this, I don't argue that GIS has to be a skill everybody has, but people have to understand space and geography. And to say we live in a global economy is an understatement. Yet, look at our general education requirements at the university. Geography isn't there. How does one propose to live in a global economy if you have no idea where Iraq is, or Iraq's neighbors are (study participant 14, interview, August 27, 2007).

Study participant 26 (interview, June 19, 2006) further went on to explain why this is so important as in relation to the public interest:

And, so the ecological address is a watershed, what's your closest stream. Where does the water go that you dump out of your sink? When you flush your toilet where does that stuff end up? Knowing where the air pollution is coming from, all those things are important. I think when you take science and make it relevant to where a person lives, works plays, then it becomes a lot more real. I think you can energize people around that idea.

The links between rational water policies and local issues, such as the use of wastewater to provide drinking water, thus illustrates the public interest theme in participants' remarks. What will be needed to bring about wider acceptance of spatial thinking, therefore, is increased awareness by educators of not only such linkages but also their connections to daily practices, such as students' water consumption habits.

### Administrative Capacity

The administrative capacity theme supported rationale as to why spatial thinking may be a value in present or future educational leadership job function. Study participant 12 stated, “I do see GIS data becoming more and more of a research tool for certain school districts” (interview, July 9, 2007). Study participant 12 further indicated that GIS is helpful in decision-making matters “as a tool for identifying demographic traits of students”. Study participant 12 specifically noted, “School attendance. It was interesting when I was involved in a project in 1987 starting with the TIMS software for our school buses”. Moreover, the participant 12 conveyed the following:

I think the thinking of GIS needs to be challenged in the field by the people who use them and not rely on the GIS technician to be sole source of supplier of the knowledge of GIS. I think what makes our operation unique is Mike is a mathematician using GIS. And we have a statistician using GIS and they have potential to use those using GIS as a tool by using mathematical background as a driving force, not the other way around. Otherwise, if you have a GIS technician to do maps they are limited on what a map can do (interview, July 9, 2007).

Here, a person who was not from educational leadership presented evidence of specific and crucial aspects of educational leadership in the practice. However, a viewpoint was indicated the showing obstacles towards acceptance as the following:



There are three things preventing further use of this. First, GIS has a software package that's still too hard to use. It takes training or at least practice and that's where things like Google and MapQuest and games are going to set the stage because they don't take that. So they're at the fringe of what GIS can do. But I think that's where the action is because the software companies make very robust, analytical products and have kept their base product too hard to use. So in the K-12 arena that's one thing; ease of use of software and easier to use packages; and they're coming (Study participant 2, interview, August 21, 2007).

Study participant 12 also suggested another area where spatial thinking contributed significantly to policy planning and development:

Redistricting between schools. How do they balance the school demographic? In the new school what would the attendance boundary be and how many students will be residing in the schools. Before the TIMS software came about in the school district, what they had was a textured description. You following Highway 64 to so and so creek; you follow that creek east and that's the description legally documented. They never had a visual map to see it. That was the first time in school history they used a map for school attendance (Study participant 12, interview, July 9, 2007).

In addition, from a state initiative perspective, Virginia's Geospatial Instructional Applications Initiative (Department of Education of the Commonwealth of Virginia, 2006), a current educational policy, generated this comment:

The way I would perceive that is in Virginia we have an initiative where we have provided a site license for GIS for all middle and high schools and that's come from folks in our state department of education who put forward initiatives to provide the funding for this. So I would say that in Virginia we are seeing, from a policy standpoint, GIS starting to get some traction. I think that it's somewhat limited and I think our implementation has been spotty but this is more than what's going on in a lot of different states (Study participant 4, interview, September 5, 2007).

Similar precedent setting work in North Carolina in research by Taylor, Vasu, and Causby (1999), a Johnston County, North Carolina study, was the basis for sustainable GIS activity by superintendents upon which study participant 12 commented. Here, participant 12 elaborated further on the use of geographic information in planning:

I pulled up the latest Johnston County layer. We have a long history with them and we're very familiar with the data that is coming through. And what I notice is that when you go from one year to the next, parcel lines change; their boundaries actually change. They're jagged; you can tell there are creeks and stuff like. I was wondering who decides when these things do change; maybe they've got new

surveyors to ok them. You don't see a stamp on the GIS layer saying this is official and here's the county line. The GIS department okays it but it's just a bunch of lines; it doesn't make any difference. They're a clearing house for the data. You don't know where the data is really coming from. I can show you many cases where there are layers that are suppose to be interlocking, do not. So they're getting it from different sources. I wasn't aware of this lawsuit but it's a problem (Study participant 12, interview, July 9, 2007).

Here, the question could be raised to as how educational leadership can rely on GIS from consultants if they do not know the precision, accuracy, and bias of the instrument.

Perhaps a GIS experience would move the profession to be able to manage such data collection. Educational leadership is still responsible for the data and would be more accountable if they shared the experience of validating the data. Participant 12 stated the following about GIS being accepted in policy:

I think it gains acceptance in policy but it has a misguided progress. There is a misguided perception that using GIS is just maddening. A lot of our experiences exposed to school districts that using GIS for them is what is seen on a map. It's more a visualization tool than anything else. And there is very little understanding about the data or the potential that the data can be derived behind those maps. Behind those maps I think there's very little understanding on the data driving those maps (interview, July 9, 2007).

Moreover, a participant stated the following when asked about the awareness of GIS policy in 50 states:

I'm not certain. There are four other states that have state licenses that might be places to go and have a look. What you're starting to see now is that in some of the state standards, you're starting to see GIS and GPS actually mentioned explicitly and that's true in Virginia and it's becoming true in other states. I think if you talk to people in 50 state agencies and you ask them if they have GIS policy they'd look at you with a blank expression (Study participant 4, interview September 5, 2007).

When asked about possible administrative applications of spatial thinking another participant responded this way:

GIS is a powerful policy tool in every policy area including educational planning and management. You can use GIS to plan housing or economic growth or save trees and you can use it to better understand educational planning (Study participant 5, interview, September 13, 2007).

In addition, in reference to North Carolina policy in realm of education was discussed as follows:

There was a later mandate in 1991-1992 about all the school districts would have to have a TIMS or equivalent software base for the school buses. I guess the detail is behind the law while you have a GIS, what are you going to do with it.

As far as a school superintendent is concerned, they got it and it is a project managed under DPI. So DPI has it too (Study participant 12, interview, July 9, 2007).

Study participant 25 (interview, September 10, 2007) stated that GIS is a major research tool: “There’s a whole bunch of projects on population environment and they’re using GIS and spatial, and also heavily remote sensing [GPS] data”.

Moreover, study participant 25 indicated what may be a result of the 1994 National Spatial Data Infrastructure Act whereby data is in a GIS format and researchers have to become familiar with this data-driven process. It was commented as follows:

Let me give you another example of how we use spatial methods. I have to present this week to OMB, the Office of Management and Budget. We’re one of the sites for the national children’s study, which is a huge national prospective cohort study that are going to recruit a hundred thousand kids and follow them until they’re 21 (Study participant 25, interview, September 10, 2007).

In addition, another example emerged as evidence as to how educational leadership could utilize GIS in educational planning:

Right now, the UNC system is in this process of trying to plan for 80,000 more students ten years from now. The question is where are they, where do they come from, where are they going to be, what kind of people are they? Where should we

providing opportunities? Should we have branch campuses. If so, where should they be? All that stuff (Study participant 26, interview, June 19, 2006).

Educational planning that is data-driven is a major consideration of educational change.

A leader of a research category I university noted that GIS use aids environmental awareness in education:

Yes. We've had a program at the university. I think it's actually called the space programming. It's a Saturday program for kids. And one of the most popular programs has been a GIS one where the kids can do some environmental work in their own environment and see where they live, and they can plot the data there.

And I think that it brings the message home. I've always been an advocate of this idea of understanding your ecological addresses (Study participant 26, interview, June 19, 2006).

Such findings suggest that educational leadership should broaden its present set of decision-making tools to include those with demonstrated applicability to spatial issues. And, as will be discussed in the next section, these tools may also help educational leaders meet NCLB demand for increased use of technology as a teaching tool.

#### Classroom Use

The classroom consideration theme provided a rationale for educational leadership's support of spatial thinking in student learning and teacher development. As one participant put it,

I would empower all the current principals and teachers to have complete access to technology that's out there emphasizing the things that could be done without having to take any training. I think there's enough innovative use or opportunity and things that don't need elaborate training and backup in hardware and software (Study participant 2, interview, August 21, 2007).

A teaching experience was described as follows:

I was also a math instructor and noticed [that] the courses that I taught required you to visualize. You couldn't solve problems unless you visualized things. You could spot students that could do it well and students that could not do it well. Don't know how that's developed. I think it's complicated because I think it's something that goes back way back in a child's development. I think it's a deep thing. But I don't know where the connection with GIS comes in. But I agree about spatial thinking being something that is lacking in education (Study participant 12, interview, July 9, 2007).

In addition, teacher freedom could be an issue as educational leadership and research wrestles with NCLB and definitions of the learning experience, as study participant 15 suggested:

It was positive for me to take a boring teaching position and turn it into something exciting. I could do world research with my students. I could investigate

problems that I couldn't investigate on my own. I have the freedom to do that (interview, July 19, 2007).

Similarly, study participant 7 (interview, October 5, 2007) stated, "It's a necessity and demand. The more complex the infrastructure becomes globally, the easier it's going to be."

Open-mindedness was advocated as follows:

They have to have more open mindedness amongst and more experience.

Administration, they're not in the classroom. The demand is going to come from the students. My brother goes to XYZ school and he understands it. That's where demand in the school comes from. You'd have to have faculty who are open minded enough and have an understanding of technology to know what to do in order to develop the curriculum assuming they're open minded enough to bring the GIS and spatial thinking curriculum in (Study participant 7, interview, October 5, 2007).

Also, it was explained how the educators may develop a GIS skills set:

I think for one you have to be able to start training the teachers that are in the classroom and offer them the opportunity to get out and to learn GIS and give them the resources to be able to use it in the classroom. That's for people already in the system. People out of the system should be able to come in with social



science or science teachers that have classes in that so that they learn GIS and geospatial thinking (Study participant 8, interview, July 2, 2007).

Another participant was stated that

I see the primary driver of GIS policy in education as being funding for the hardware and software necessary to support GIS learning and the availability of GIS curricula that are grade-appropriate. Computers are widely accepted now as essential to K-12 learning but to use GIS there must be an additional investment in software and teacher training and, frankly, the computers themselves have to be pretty new. Teacher attitude is also a critical factor (Study participant 23, interview, August 22, 2007).

In addition, it was acknowledged as follows:

I think something schools are not particularly good at is helping kids understand why they're taught particular subjects. Adult education recognizes that one of the best ways for adults to learn something and retain that knowledge is for them to apply what they've learned. A great deal of the education system does not seem to recognize this precept. GIS is a fabulous tool for applied learning and enhances both knowledge retention and critical thinking at all levels of education (Study participant 23, interview, August 22, 2007).

Hence, classroom use of GIS in education was found congruent with White (2005), Hagevik (2003), Kerski (2000 and 2003), Alibrandi (2003), Alibrandi, Hagevik & White

(2002) and Alibrandi & Palmer-Moloney (2001) because it may combine locally relevant data and geographical data in a student learning process.

Other participants saw great potential for spatial thinking both within the schools and in the community. Participant 6, for example, mentioned that “Most recently, I developed a program in the Detroit public schools on urban environmental education which would make a model for urban use by having high school students interface with elementary school students in bringing math and science” (Study participant 6, interview, September 14, 2007).

Participant 6 (interview, September 14, 2007) also noted, “I think that GIS activity brings schools and communities together. If you know how to use GIS then you should go out and do something with it.” Participant 13 made much the same point with reference to the use of GIS in “the law and business applications” (interview July 3, 2007) and cited practices in other countries as a possible model as follows:

I know it’s much bigger in Europe. For example, you can go to Denmark and you can look there at the whole town, all the streets, all the points of interest. I met an individual that had headed up that part of that project and he said they actually had online voting (Study participant 13, interview July 3, 2007).

Recently, there has been a real call nationally to institute GIS as a subject. Canada has geography as a subject. Our geography is enrolled as social studies and that puts it second. So there’s a call now to make geography a subject in the country

and that is related to what you are talking about (Study participant 13, interview July 3, 2007).

A national perspective of GIS was indicated as follows:

I think that it's more of a snowball and it's already going and it depends on who gets on board and when. Look at Maine, Texas, Montana, Nevada and Colorado. There are five states that have statewide software licenses for every school in the state. That should tell us something. And I think they're adding it in North Carolina as a statewide university license (Study participant 13, interview July 3, 2007).

A specific example of why educational leadership and research must get involved in GIS that was already present in educational operations was communicated as follows:

Administrators actually have been really interested in using GIS and a lot of them are anyway. Their school systems are using it for figuring out how to draw the lines; how to do districting, especially in North Carolina. The whole state of North Carolina uses it throughout their all schools. So they have to work with it whether they want to or not because of those two things. So they are very interested in using it. I know principals that use it to manage their buildings; what doors are locked when; where all the outlets are and how do you evacuate the school if there's an emergency. I found principals to be very interested in using it

because they know it's going to make their job easier (Study participant 13, interview July 3, 2007).

Moreover, the same participant indicated student experiences that educational leadership could seek to normalize or duplicate with proper teacher professional development as the following:

We did all kinds of really cool projects. We worked with Raleigh GIS and helped them with their database and looked at the growth of the city of Raleigh. So they mapped the city of Raleigh since the 1800's. They mapped the evolution of the railroad system. They did a project with the zoo with the elephants in Cameroon and they tracked the maps in Cameroon. And then the zoo started using GIS after they did it. They mapped Walnut Creek and were involved in a project where they were preserving that watershed and deciding on a park being developed. They did some water quality work; a lot of different things. It's been so successful and the kids love it. They don't have problems with it at all. They're so much more technology oriented than the teachers. It's fun for them (Study participant 13, interview July 3, 2007).

Another person commented on the potential value of GIS for educational policy:

I'm not really sure what traditional educational changes are needed in the system of private education. But I think for the broader public there's a whole awareness that this is a tool that's available and the more you use it, the more people will

want it and demand it. I think more policy makers will want to see a map and not only read it, but show it and have it explained. I think the more it's used, the more demand there will be for it (Study participant 15, interview, July 19, 2007). In addition, evidence that GIS skills could be linked to NSF capacity and activity whereby funding may be a consideration:

First of all, who I am. I am a professor of sociology ... I use spatial data and methods in my research. I talk about them in my teaching. I'm also the Principal Investigator of a training grant with NSF that includes spatial thinking methods as an essential part of its training (Study participant 25, interview, September 10, 2007).

In addition, the following was communicated:

There are some people who become transdisciplinary. And what that means is they are deeply and intricately trained in more than one discipline. It's as if I were a geographer to the point where I was making major contributions to GIS methodology, while at the same time I'm leading the demographic community (Study participant 25, interview, September 10, 2007).

#### Policy and Research

Lastly, issues in the theme of policy and research were discussed. The policy and research theme begins with general suggestions of geography in the curriculum. Such a concept was suggested by the 1997 Leandro article 2 (North Carolina Administrative

Office of the Courts, 1997). Other recommendations of what is needed include a rationale to overcome resistance towards acceptance of spatial thinking.

Study participant 17 stated that the basic problem was “a lack of awareness of the extent and importance of spatial thinking”, and went on to suggest that “geography needs to be a core subject in schools” (interview, July 13, 2007).

In a similar view, study participant 19 indicated that,

There are several things that make the education community resistant to change: They do not know the technology. They do not know how to apply the technology. They cannot do problem based learning (interview, September 17, 2007).

The absence of GIS is not solely a problem in the United States. Thus a participant familiar with the situation in South America said,

Here in Curitiba there is only few people using GIS for education purposes, thus my understanding is that most of the teachers and principals as other school administrators do not know this tool or how it can be used in education. As for the state school system, I was the only and first one educator on the course ever. Nonetheless, this year (2008) I realized that the state school system is trying to use GIS to enroll kids on schools that are closer to their homes (this is because some schools are crowded and kids cannot stay there even if it is close to their homes, thus the state has to find other schools for them). They are also trying to

use GIS on the teacher transfer process (based on home location) (Study participant 27, interview, January 13, 2007).

Nevertheless, not all participants agreed with the view that GIS is generally underutilized. Participant 5, for instance stated that “GIS is a powerful policy tool in every policy area including educational planning and management” (interview, September 13, 2007). Here, educational leadership and research may catch on to the ability to make decisions and encourage others. However, study participant 22 stated the contrary perception:

I don't think it's going to catch on. Teachers aren't going to do it unless it's encouraged at the administrative level and the policy level. There has to be fundamental change in the way the schools are structured in order for it to catch on, plus a lot more money to be spent on technology (interview, September 28, 2007).

The following was offered a simple rationale as to why GIS is needed as an essential tool of educational leadership:

Geography gives you a way to put those things together and begin to predict outcomes. Then that means it doesn't so much align; it's not teaching math but it certainly is the application of that. And maybe that's more important than skill and mathematics, is the skill to apply it to problems of importance (Study participant 14, interview, August 27, 2007).

Insight on how North Carolina policy could further engage educational leadership was communicated as follows:

What the GICC has mostly done is come up with standards so that the data that's in universities and the data in state government and local government can all connect together. So it's really been more about coordination and standards and less about universities or public schools; here's what you got to have. The council could probably be more assertive in that area but we've still got a long ways to go (Study participant 15, interview, July 19, 2007).

How GIS is used by government is evidenced as the following

Here's a good example, a policy situation. Geographic information is playing a significant role with us right now; not necessarily in a positive context as far as we're concerned. But nonetheless, it's bringing the issue to the fore and the geographic information is doing it. We as municipalities in the state are concerned about the issue of annexation. Our organization is very much in favor of municipalities retaining their ability to annex the tax issue. It's not just a tax issue. People don't want to be riding into the city limits because they don't want to pay the taxes. The problem is they want to utilize the city services and it's the city people who are actually paying these people who are outside the city (Study participant 16, interview, June 28, 2007).



Lastly, about GIS and demographic data, which is a major consideration for educational leadership, it was commented:

Entering into the debate, is an issue of racial discrimination associated with annexation or the lack of annexation? A GIS study was done by UNC which showed that areas that have been in several communities, traditionally underserved and were primarily poor minority areas, were not being annexed by the community, and that was shown in the map context. And it's clearly borne out by demographic and boundary lines and you can look at it from a mapping perspective (Study participant 16, interview, June 28, 2007).

In addition to policy, participants also suggested a future role for spatial thinking in educational research. For instance, study participant 22 mentioned that

There was recently a report by the National Research Council on wanting to work spatially which was pushing heavily on the idea that more research needs to be done to see the potential of GIS and they attempted to come up with a broad analysis of what geospatial thinking looks like (Study participant 22, interview, September 28, 2007).

A similar comment was made with reference to the educational system in Brazil:

“As for research, I saw on this course that most research presented to the students was based on traffic and city management and also on environmental perspectives” (Study participant 27, interview, January 13, 2007).

Study participant 23 offered a different perspective as a data librarian:

I see GIS as gaining rapid acceptance in policy, classroom use, and research. In terms of policy, nearly all of North Carolina's 100 counties use GIS one way or another. My perception of the reason for this is the ease it lends to management of tax parcels and the critical need it fills in handling the damage done by natural disasters (interview, August 22, 2007).

#### Implications of findings for theory development

An awareness of the spatial thinking culture needs to be recognized formally and managed for consideration at national, state, and local levels. Study participant 17 (interview, July 13, 2007) specifically mentioned awareness. Various communities need awareness that a common infrastructure of data access is possible in a cost effective manner.

Participant 13 stated, “It’s a moving target like any technology” (interview, July 3, 2007). This is a challenge for all policy makers, educators, and others if the spatial thinking culture changes before policy and a group perception can form. Ultimately, this suggests that subgroups at various levels—national, state, and local—have to work independently and then collaborate through review committees and such feedback in order to make effective policy.

Study participant 14 (interview, August 27, 2007) and participant 22 (interview, September 28, 2007) indicated that spatial thinking should be added to the standard

course of study in problem-based learning experiences. Moreover, earth science policy at the federal level is critical to adding survivability skills of spatial thinking described by participant 14 (interview, August 27, 2007) to the K-12 experience. Federal direction might synergize state and local school boards to consider having the 21<sup>st</sup> century skill movement include spatial thinking as an interdisciplinary consideration.

Ultimately, spatial thinking communities should be better united and organized to collaborate in advancing spatial thinking policy at the K-12 and other levels. As indicated by participant 8 (interview, July 2, 2007), there must be a national policy champion for encouraging participation. This champion or an emerging set of champions may need to bring some debate, synergy, strategic planning, and research to the public awareness in order to reach the educational agenda. In addition, the issue of federal agencies advocating on behalf of a spatial thinking culture creates a major dilemma, because they are government agencies and may not be able to comment on existing government policy. Agencies such as National Oceanic and Atmospheric Administration, National Aeronautical and Space Administration, and other sensitive federal agencies can highlight the true power of the spatial thinking community.

It can be inferred that the National Academy of Science's (2006) call for spatial thinking at all levels of education is just rhetoric. As this organization calls for spatial thinking at all levels of education, any pragmatic procedures and policy to move it into professional development, teacher training, and standard course of study rubrics is

lacking on a national basis even in the shadow of federal mandate, Executive Order 12906. This study suggests that the National Academy of Sciences (2006) and the National Science Foundation (2006) efforts should promote and develop grants for spatial thinking educational leadership to use to develop practical solutions at national, state, and local levels; in addition, they should develop K-12 prototypes and pedagogical bridges in higher education. The issue here is that spatial thinking has to be formally sustainable in K-12 and higher education settings if the National Academy of Science's (2006) rationale is to move from rhetoric to pragmatism. Open-mindedness to future NCLB considerations is required whereby spatial thinking can be included in the standard course of study in problem-based formats. This is a practical consideration if support and research in spatial cognition, how the brain works in such activity, and learning in spatial thinking experiences for K-12 can be validated and proven cost effective. Moreover, if a state has a GICC board, links to education should go beyond a GIS initiative, as in Virginia, to aid effective innovation and research for spatial learning development.

In simpler terms, there is enough evidence to warrant spatial thinking or GIS professional development or training. For example, study participant 17 stated,

I see spatial thinking as essential in virtually all disciplines. GIS and an emphasis on the surface of the Earth are relevant only in the social and environmental sciences, but spatial thinking can also enhance education in disciplines as diverse as mathematics and dance (interview, July 13, 2007).

Similarly, a rationale justifying a possible slow acceptance of spatial thinking in the social sciences could be identified via the following perspective as study participant 13 stated:

Public policy is more like the social studies side of education. It has to do with not only the data, but how people feel about what's happening. There's more that goes into the decision than just data. It also has to do with people's priorities and values; things that you cannot quite put your hand on. And that's where public policy comes in. The people that think that way are not necessarily good at spatial technical kinds of things. It's a different way of thinking and this is why maybe it's been slower in that area. It's completely throughout science. So you may want to think of it that way. In public policy and social studies it's a different kind of approach that doesn't match as well (interview, July 3, 2007).

#### Summary of Chapter 4

Chapter 4 discussed findings in the themes of public interest, administrative capacity, classroom use, and policy and research. Such implications were briefly discussed. Chapter 5 discusses conclusions derived from Chapter 4. In addition, a theory of spatial thinking from educators' perceptions will be discussed with future research implications.

## CHAPTER 5

### Conclusions

The chapter summarizes the major conclusions of the study, and considers its implications for educational change and theory, and, while acknowledging the study's limitations, shows how it may point the way to future research on spatial thinking's role in education.

The themes that emerged from the findings were public interest, administrative capacity, classroom use, and, policy and research. These findings address the aspects of educational change sought in the study's research question: What aspects of educational change do participants believe must occur in order for a GIS/spatial thinking culture to reach widespread implementation? Table 5.1 briefly illustrates each of four themes.

Table 5.1

Evidence of spatial thinking findings

Generated themes	Illustration
<b>Public Interest</b>	"The activities in GIS of the state agencies and their counterparts in the federal government and local government are to be done to the extent they can be coordinated through this government committee. So it's not requiring agencies to use GIS. But it's requiring GIS programs within agencies to have a linkage back to this council". (Study participant 2, interview, August 31, 2007).
<b>Administrative capacity</b>	Study participant 12 stated, "I do see GIS data becoming more and more of a research tool for certain school districts" (interview, July 9, 2007).

Table 5.1 continued

<b>Classroom use</b>	Study participant 19 (interview, September 17, 2007) stated, "The values of GIS as a decision making software needs to be accepted." In addition, study participant 19 further stated, "In order for geospatial technology to be accepted a participant commented such has to be valued: Ability of students to solve problems without directions, group work, and, presentation skills" (interview, September 17, 2007).
<b>Policy and research</b>	Study participant 22 stated that, "The National Research Council would like to see how spatial thinking in education may look" (interview, September 28, 2007). Also, study participant 12 stated, "There was a later mandate in 1991-1992 about all the school districts would have to have a TIMS or equivalent software base for the school buses" (interview, July 9, 2007).

### Implications for educational change

Certainly, education should advance citizenry towards recognizing and taking advantage of policy, technology, and innovation that benefits society. Greater acceptance, awareness, and implementation of spatial thinking are the targeted goals of this study. Change in the philosophy and practice of education is vital to achieving optimal problem examination and decision-making because school issues change over time. A plausible resulting effect will be a more enhanced engagement in the public interest, administrative capacity, classroom use, and policy and research aspects of education.

Implications from the interviews with the study participants included the following:

1. A need to observe values for classroom use towards spatial thinking was supported. This notion reflects the classroom theme.
2. A spatial thinking policy has been present twenty-five years in formal policy past for the North Carolina Department of Public Instruction's (DPI) Transportation Division. (See for example, North Carolina Public School Law– pupil transportation 115C-240 sub-section d) This illustrates the administrative capacity and policy themes emerging from this research. Yet, this has not evolved into spatial thinking content within the state's Standard Course of Study. This may be a consideration for educational renewal.
3. Open-mindedness, intentional learning, and educational renewal may be valid approaches of towards expanding the role of spatial thinking in education. Such may include a reinvention of geography in education, which, as indicated in the 1997 Leandro article 2 (North Carolina Administrative Office of the Courts, 1997), is a part of sound basic education. Here, geography is suggested as being a component of spatial thinking, in expectation that using the tool of GIS may satisfy the Leandro article 2 requirements. This idea reflects the public interest and policy themes.
4. The spatial thinking experience of data collection, data verification, and data analysis is not on the radar of educational leadership. If this spatial thinking experience is a common occurrence in the Science, Technology, Engineering and Math (STEM) disciplines, then such awareness may be valid for future educational leadership consideration because it could be instrumental in addressing pipeline outcomes in STEM



disciplines required by No Child Left Behind (NCLB). This notion reflects the policy and research theme.

### Implications for theory

In addition to its practical implications, this study also suggests some ideas for future theoretical development, specifically with regard to stimulating a broader role for spatial thinking concerning public interest, administrative capacity, classroom use, and policy and research that may generate educational renewal. Collectively, all the themes may benefit from open-minded discussion, debate, and attempts to intentionally learn and implement spatial thinking. Three main postulations were generated as follows:

1. A spatial thinking vocational experience should be included in both the philosophy and practice of K-12 education, with coordinated support from higher education. Dewey (1916) stated that learning by doing may be a practical realization.
2. Educational leadership and researchers may have to renew their relationship to join forces to advance spatial thinking in education. Coleman (1990) stated that a feedback system is critical towards advancing change. In addition, Coleman (1990) implied that foundational studies are essential towards building social constructs. In practice, education may have the task of building the social constructs of spatial thinking such that educational practices can change. Lin (2001) called such a device a social bridge. Thus, spatial thinking can act as a bridge of learning for the next generation, as well as a bridge for understanding and implementing policy for the present generation.

3. Education could demonstrate intentional learning, open-mindedness, and renewal in the support of spatial thinking. As an information technology, GIS has implications for retraining and integrating technology in education in ways that may benefit society. In general, such an intentional focus by education in further compliance with Executive Order 12906, Coordinating Geographical Data Acquisition and Access: The National Spatial Data Infrastructure (Federal Geographic Data Committee, 1994) and state GICC policies may affect national recommendations concerning a geospatial workforce shortage (United States Department of Labor, 2005).

A main reason that education should consider spatial data use emanates from Executive Order 12906, section 1 (a), which defines National Spatial Data Infrastructure (NSDI), as the “technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data” (The White House, 1994, p. 1). In softer terms, the NSDI strategy can be stated with the purpose to define what “current and accurate geospatial data will be readily available to contribute locally, nationally, and globally to economic growth, environmental quantity and stability and social progress” (Federal Geographic Data Committee, 1997, p. 4).

Federal policy thus advocates spatial data use as a critical national interest. In response, the North Carolina GICC legislation (General Assembly of North Carolina, 2003; and North Carolina Geographic Information Coordinating Council, 2003, 2006,

2008) requires all state agencies to work towards a spatial data standard for exchanging information. Thus, further educational change could be anchored from this notion.

The public interest theme, as well as other themes emerging from this study suggests that for 21st-century educational leaders, effective communication involves the management of spatial data and its presentation to stakeholders. “While increased accountability is just one part of NCLB, all schools must gather data and overcome barriers to analyzing and using the data” (Bernhardt, 2004, p. 125). Thus, spatial thinking should be a normal part of overcoming barriers or adjusting to changing metrics and methods of data collection and analysis.

A similar conclusion is warranted by findings for the classroom use theme, which suggested teacher freedom was a benefit of spatial thinking if the proper professional development is provided. Such classroom use findings of GIS are congruent with the works of White (2005), Hagevik (2003), Kerski (2000; 2003), Alibrandi (2003), and Alibrandi, Hagevik and White (2002), all of which advocated an increase of GIS in the K-12 classroom. Alibrandi & Palmer-Moloney (2001) indicated that GIS in the classroom involves locally relevant issues and geographical data in a student learning process that may increase student civic capacity, about which Alibrandi (2009) stated, “Students applying GIS are working with real world problems. In so doing, the learning and assessments are authentic--they are addressing environmental and social problems on the ground with a professional application. Thus, their learning and the products of their

work can contribute directly to their local communities” (personal communication, February 10, 2009).

NCLB indicated the importance of practices and programs with respect to assessing the at-risk student population (United States Department of Education, 2002). Effective examination and decision-making from data management goals referenced in NCLB guidelines, such as juvenile delinquency, migratory children, and other required data assessments, are essential to education’s role in a democracy. Such democratic data use is the mainstay and the defining motive for education because it can advocate intervention or improvement programs if educational leaders can determine and predict where the issues are geographically located in their authority. This argument would proclaim that education will benefit from being able to have data-driven decision models that indicate where potential issues may emerge and the strategic planning needed to remedy such occurrences.

For example, how can educational leadership support the public interest without knowing where the disadvantaged children are located, or other educational trouble spots such as gang activity, absenteeism, or high school dropouts? Hence, educational leaders have to know the geography of their district and be able to respond to public interest from a data-driven manner. Taylor, Vasu, and Causby (1999) conveyed similar thought in a study where spatial data was rendered in an empirical manner as evidence for decision-

making by school districts. In this case, leadership faces spatial problems and GIS may be very helpful in analyzing data.

In summary, the educational community should consider the public interest, administrative capacity, classroom use, policy and research themes derived from the findings as opportunities to use spatial thinking in both philosophy and practice. Education's task to comply with federal and state policy may emerge first in public interest and administrative capacity venues and then aid further development in classroom use, policy and research.

#### Limitations of Study

The limitations of the study were most notable in the interview process, which used a small sample size drawn primarily from a single region within the state of North Carolina. And although all interviews followed the same protocol and posed the same questions, difficulties in scheduling necessitated that some interviews be conducted by phone or email, as opposed to the preferred in-person format. Finally, the exclusive reliance on interview data and the absence of data against which the participants' statements might be triangulated must be acknowledged as a significant limitation.

#### Future Research

Despite these shortcomings, this study contributes to the as yet sparse literature on the role of spatial thinking in contemporary elementary and secondary education. It does so by soliciting ideas from varied practitioners and policy-makers in this field and

highlights the significance of certain developments, including Executive Order 12906 and the Fifty States Initiatives (National States Geographic Information Council, 2009), which seeks compliance with spatial management data by state agencies. “The Fifty States Initiative is a partnership between the National States Geographic Information Council (NSGIC) and the Federal Geographic Data Committee (FGDC). It is designed to bring all public and private stakeholders together in statewide GIS coordination bodies that help to form effective partnerships and lasting relationships” (National States Geographic Information Council, 2009). One avenue for future research, therefore, would be broader, more intensive analyses of the possible impact of these initiatives on both classroom practice and decision making in local school systems.

Future research may confirm the study’s theory implications and define further consequences of a spatial thinking experience throughout educational functions. The work of Taylor, Vasu, and Causby (1999) benchmarked GIS use by superintendents in 10 counties in North Carolina should be further investigated with this study’s finding of a perception stating that GIS use was currently involved in nearly 100 North Carolina counties by study participant 23 (interview, August 22, 2007). More work to correlate the use of data-driven GIS tools to the superintendent retention rates should be explored further as referenced by Taylor, Vasu, and Causby (1999).

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## Appendix A: Instrument

## Interviewing Protocol

Project: A Theory of Educational Change from a Spatial Thinking Culture

Time of Interview:

Date:

Place:

Interviewer:

Interviewee:

Position of interviewee:

The purpose of the project is to generate a theory as to what types of educational change can be promoted by an educational professional who supports, advocates and seeks further expertise in spatial thinking paradigms or the use of geographical information systems. Please note all information will be kept in strict confidence and reported in terms that provide anonymity for your participation.

### **Preliminary questions:**

May I have your permission to record this interview?

Yes    No

Do you understand these findings will be reported under terms of anonymity?

Yes    No

May I contact you for follow-up on your comments?

Yes    No

**Questions:**

- 1) What type of educational researcher/policy [study] participant are you? Are you an educator, educational researcher, policy maker, future educational grant applicant, grant funding agency personnel, or other?
- 2) What is your experience with GIS/spatial thinking? How did you get interested in this approach? How do you think a spatial movement could better serve the student experience in K-12 education or researcher experience and why is that?
- 3) What influence do you see as being the primary driver of GIS policy in education?
  - How do you see a spatial thinking culture involved in the future of education and policy development?
  - What ways of thinking do you perceive are enhanced by GIS applications at various levels of education?
- 4) Are rubrics and standards needed for student experience and teacher professional development?
  - What connections between school and community do you think can be enhanced by GIS activity?
- 5) How do you perceive GIS as gaining acceptance in policy and classroom use?
- 6) What aspects of educational change must occur in order for a GIS spatial thinking policies to emerge?

- 7) Do you think a spatial movement can only emerge from a vast reorganization and reconstruction of educational policy?
- 8) What was your biggest issue of resistance to spatial thinking paradigms of GIS as an educational professional?
- Do you see a need for all educational professionals to be spatially literate or GIS proficient? Why or why not? What kind of change did it present for you?
- 9) What types of reform do you think are best for a spatial thinking culture? What role does communication of data play in this consideration?

Thank you so much for your participation!

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## Appendix B: IRB Consent Forms

North Carolina State University  
**INFORMED CONSENT FORM for RESEARCH**  
A Theory of Educational Change from a Spatial Thinking Culture

Principal Investigator B. Dewayne Branch  
applicable) Dr. Paul Bitting

Faculty Sponsor (if

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**We are asking you to participate in a research study. The purpose of this study is to generate a theory of educational change from a spatial thinking culture.**

**INFORMATION**

**If you agree to participate in this study, you will be asked to Complete a pre-qualifying survey, be in up to 3 or less recorded interviews, have all agree to terms of confidentiality, and be available for possible follow-up**

**RISKS**

There should be no risks, all are adult professionals and we may building a theory of educational practice collectively from the data generated.

**BENEFITS**

The educational leadership and various forms of educational researchers will gain insight, empowerment and a consensus in the effort to advance the use of spatial thinking in education.

**CONFIDENTIALITY**

**The information in the study records will be kept strictly confidential. Data will be stored securely in on a crypto secure flash drive and a personal computer with only researcher access No reference will be made in oral or written reports which could link you to the study.**

**COMPENSATION (if applicable)**

**For participating in this study you will receive nothing. If you withdraw from the study prior to its completion, you will receive still nothing. If students will receive class credit for participating, include: **Other ways to earn the same amount of credit are none.****

**EMERGENCY MEDICAL TREATMENT (if applicable)**

This is not applicable to my research.

**CONTACT**

**If you have questions at any time about the study or the procedures, you may contact the researcher, principal investigator B. DeWayne Branch, at [REDACTED], or [REDACTED]. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)**

**PARTICIPATION**

**Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.**

**CONSENT**

**"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."**

Subject's signature \_\_\_\_\_ Date \_\_\_\_\_

Investigator's signature \_\_\_\_\_ Date \_\_\_\_\_

North Carolina State University

**INFORMED CONSENT FORM for RESEARCH**

A Theory of Educational Change from a Spatial Thinking Culture

Principal Investigator B. Dewayne Branch  
Bitting

*Follow-up 1 Questions #1-4* Faculty Sponsor (if applicable) Dr. Paul

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We are asking you to participate in a research study. The purpose of this study is to generate a theory of educational change from a spatial thinking culture.

**INFORMATION**

If you agree to participate in this study, you will be asked to expand on any further input you have from the interview questions from the original interview. There will be two follow-up sessions where you can respond in person, email or telephone interview. The primary focus is to see if there are any updates or additional information that you'd like to share. Each follow-up session may focus specifically on 2-4 previously asked questions of the original interview questions. Questions may differ among each participant.

**RISKS**

There should be no risks, all are adult professionals and may skip any question that makes you uncomfortable. We are hoping to build a theory of educational practice collectively from the data generated.

**BENEFITS**

Through this research, we hope to gain insight, empowerment, and a consensus in the effort to advance the use of spatial thinking in education.

**CONFIDENTIALITY**

The information in the study records will be kept strictly confidential. Data will be stored securely on a USB drive and a personal computer which only the researcher and his advisor will access. No reference will be made in oral or written reports which could link you to the study.

**CONTACT**

If you have questions at any time about the study or the procedures, you may contact the researcher, principal investigator B. DeWayne Branch, at [REDACTED], or [REDACTED]. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact David Kaber at, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919-515-3086) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)

**PARTICIPATION**

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

**CONSENT**

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature \_\_\_\_\_ Date \_\_\_\_\_

Investigator's signature \_\_\_\_\_ Date \_\_\_\_\_

North Carolina State University  
**INFORMED CONSENT FORM for RESEARCH**  
A Theory of Educational Change from a Spatial Thinking Culture

Principal Investigator B. Dewayne Branch  
Bitting

*Follow-up 2 Questions #5-8* Faculty Sponsor (if applicable) Dr. Paul

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We are asking you to participate in a research study. The purpose of this study is to generate a theory of educational change from a spatial thinking culture.

**INFORMATION**

**If you agree to participate in this study, you will be asked to** expand on any further input you have from the interview questions from the original interview. There will be two follow-up sessions where you can respond in person, email or telephone interview. The primary focus is to see if there are any updates or additional information that you'd like to share. Each follow-up session may focus specifically on 2-4 previously asked questions of the original interview questions. Questions may differ among each participant.

**RISKS**

There should be no risks, all are adult professionals and may skip any question that makes you uncomfortable. We are hoping to build a theory of educational practice collectively from the data generated.

**BENEFITS**

Through this research, we hope to gain insight, empowerment, and a consensus in the effort to advance the use of spatial thinking in education.

**CONFIDENTIALITY**

**The information in the study records will be kept strictly confidential. Data will be stored securely on a USB drive and a personal computer which only the researcher and his advisor will access. No reference will be made in oral or written reports which could link you to the study.**

**CONTACT**

**If you have questions at any time about the study or the procedures, you may contact the researcher, principal investigator B. DeWayne Branch, at [REDACTED], or [REDACTED]. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact David Kaber at, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919-515-3086) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)**

**PARTICIPATION**

**Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.**

**CONSENT**

**"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."**

Subject's signature \_\_\_\_\_ Date \_\_\_\_\_

Investigator's signature \_\_\_\_\_ Date \_\_\_\_\_