A Conceptual Framework for Facilitating Geospatial Thinking
Abstract
In this article we investigate whether a geospatial task-based framework can be conceptualized and developed to assist in structuring (in a grade related context) a conceptual framework that could help build a vocabulary and scope and sequence structure for the geospatial thinking that makes the world and its activities legible to us. Our argument is presented in conceptual terms, but we offer preliminary evidence, based on work with local 3rd grade and 6th grade students, that a hierarchy of concepts can be developed based on complexity, and we give results from pilot experiments to illustrate the feasibility of the hypothetical framework. The pilot studies show a clear differentiation of vocabulary and concept use between the two sampled grades and provide some substantiation of the potential use of the conceptual framework.

Key Words
Task-based framework; concept lexicon; geospatial; primitives; pilot G3-6 experiments
Introduction
Humans deal with problems of incompleteness and scale using transferable spatial and geospatial concepts. A minimal set of such concepts (herein called “primitives”) consists of identity, location, magnitude, and space/time (Golledge 1995). In this paper, a pedagogic oriented geospatial learning framework is offered that is developed as an aid to the introduction and learning of geospatial concepts in a K-12 system. Although we provide evidence only for the use of the structure in an elementary school context, results of empirical experiments suggest that the framework can be extended beyond the elementary level to the middle and high school levels.

Montello (1993) has pointed out that there are several scales for spatial thinking ranging from micro-scale (e.g., in nanotechnology or microscopic examination), figural (restricted to the immediate vicinity of the human body), environmental (the immediate area in which a person lives and behaves), to geographic (the area that cannot usually be perceived from a single vantage point on earth). Geography traditionally has dealt with environmental spaces (e.g., activity analysis) and geographic space (the space of representation rather than personal interaction). Although some research (as reported in Spatial Behavior, Golledge and Stimson 1997) has expanded geographic thinking into both the figural (decision making, attitudes, preferences, emotions, values, and beliefs) and the micro level (representing and analyzing cognitive maps, place cells, DNA structures), geographers generally have traditionally concentrated on environmental and geographic spaces. This implies that “spatial” is the all-scale-encompassing general term and that the spatial thinking in geography is a subset of this general term. To maintain the link to the parent concept, in this paper we use the term “geospatial” to refer to the environmental and geographic scales. This term generally is in use in the literature of representation and analysis of geographic phenomena, and in the geotechnical domain that has become a focus of many disciplinary users. To help differentiate between spatial and geospatial activities, Table 1 gives examples of everyday micro and figural spatial activities and geospatial (environmental and geographic scale) activities.

<Table 1>

Traditionally, much of geography, as taught in the early school years, has been object-oriented. Thus, decades of students had to learn the names of mountains, rivers, capital cities, types of water bodies, classes of landforms, types of urban specialization, and so on, as well as many other components of the physical and built worlds. This detail can now be accessed at the click of a mouse in e-atlases, or in indexes, gazetteers, and other lists of objects and places (e.g., using Google Earth software). The original (traditional) tasks of learning all this information by rote produced the widely held image of geography as a declarative activity focused on description of WHAT is WHERE. But much of the geographic information contained in an environment lies in the spatial relations among objects and places. Finding these relations has formed the basis of much geographic investigation over the last half century or so. These spatial relations are captured in the form of intellectual concepts and have provided the basis for much current geographic thought and the production of much of our current geographic knowledge (see Golledge 2002; Turner 2002). The approach used here is to focus on concepts dealing with relations that can be observed or inferred as existing in the general geospatial domain.
Spatial thinking is universal, being common not only in the geosciences (NRC 2006), but in the sciences generally (Colwell 2004), in the social sciences (Lobao 2003), in history (Knowles 2000) in mathematics (National Council of Teachers of Mathematics 2000), in the arts, literature, and even in most sporting activities (National Research Council 2006). This trend is documented in materials developed for the Center for Spatially Integrated Social Sciences (CSISS, http://www.csiss.org/). In addition, the NSF funded SPACE Program (Spatial Perspectives for Analysis in Curriculum Enhancement 2004-2006; see http://www.csiss.org/SPACE/workshops/) has trained many teachers of social science in understanding geospatial thinking, while the procedures in the Geography Facility Development Alliance (GFDA) is doing the same thing.

The last decade in particular has seen direct and indirect attempts to get geography represented more in the social sciences curriculum (e.g., Core Knowledge Foundation 1995; Munroe & Smith 1998; Boehm 2002). But there is a growing sentiment that geography curricula (except for the National Geography Standards [Geography Education Standards Project 1994] and the Scope and Sequence matrix derived from the Geography for Life project [Boehm 2002]) need to be researched even further. There is a strong sentiment emerging that what is needed is a clear and concise statement of what today’s geography students should be taught and when they should learn it. This paper contributes to the process of fulfilling this need.

Despite the increasing frequency of diligent efforts to improve geospatial thinking (e.g., CSISS, SPACE, GFDA), there still is abundant evidence of the extent of geographic illiteracy in the USA. While this country and the world at large are becoming more globally interconnected, and despite considerable efforts by the geographic teaching and research communities, both the general and the student populations of the United States have been exhibiting ever increasing levels of insularity (i.e., geographic illiteracy). For example, US students are rated among the world’s worst in terms of geographical knowledge (Coyle, NEETF/Roper Report 2004; National Assessment of Educational Progress [NAEP] in Reports by the National Center for Education Statistics 2005). The NAEP report, for example, found:

- The majority of U.S. students in grades 4, 8, and 12 tested at or below the basic level (with the higher percentage at basic). Basic level achievement denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade.
- Little improvement in grades 4 and 8 (Grade 4: from 206 [1994] to 209 [2001] and Grade 8: from 260 to 262 over the same period; based on a 0-500 NAEP geography scale); NO improvement at grade 12 (from 285 to 285).

With respect to the Roper Poll which focused on young adults 18-24 years of age:

- Americans came in second to last, performing just slightly better than their neighbors from Mexico with an average of 23 correct responses out of 56 questions (41 percent correct), far behind scores from western European countries, Canada, and Japan.
- Only one in seven (13 percent) of the Americans tested could correctly identify either Iran or Iraq on a map; only 17 percent could correctly identify Afghanistan
- Nearly 1 in 3 American youths incorrectly stated that the U.S. population was somewhere between 1 and 2 billion people.

The poverty of these national indicators is often attributed to:

- The lack of a uniform inclusion of the teaching of geography in US schools
• The fact that the geography that is taught is largely taught by K-12 teachers not explicitly trained in geography
• The increase in teaching opportunities by other core disciplines such as mathematics and science has diminished the opportunities to teach geography
• The difficulty of changing school curricula to include more geography
• Despite the productive efforts of selected programs to train a cross section of teachers to appreciate geographic ideas (e.g., CSISS, SPACE), there is a lack of comprehensive training and opportunities for non-geography teachers to gain at least minimal expertise in comprehending geographic concepts and principles.

Thus, in the USA where global communication and globalization of industry, communications, and employment have become commonplace, there has been a tendency for K-12 students to become more and more geographically ignorant, not only of their own country but of their country’s place in the world at large. The argument developed in this paper is grounded in the belief that students, teachers, and society in general can benefit from exposure to effectively presented and taught geospatial concepts and by exposure to geospatial technologies such as geographic information systems (GIS), cartography (including computer cartography), photogrammetry, and remote sensing imagery, as well as by developing an appreciation for thinking spatially throughout the life span (NRC 2006). This belief was fundamental to the formation of two NRC Committees—Rediscovering Geography (1993) and Thinking Spatially (2006). The framework developed herein is the result of an extended period (Golledge 1990, 1992, 1995, 2002) of research that culminated in an NSF sponsored project on “Spatial Thinking” that benefited greatly from interaction with the members of the NRC Committee on Thinking Spatially (NRC 2006).

In the general educational system of the US, there is, indeed, a black hole that represents knowledge of both large and small scale geographic environments—from knowledge of local areas and spatial relations among objects and phenomena to the knowledge needed to understand today’s globalized societies and economies, communication networks, population movement patterns, political alliances, and economic development concerns. There is a need to redress this lack, and, currently, there is only limited place for the introduction of geospatial knowledge in most school curricula, except incidentally and within the context of already existing curricula components (e.g., in the Geometry sections of Math curricula). However, ongoing efforts by the National Geographic Society, AAG, NCGE, and other professional bodies have been aimed at attacking these concerns and have resulted in outcomes such as having geography defined as a core subject in many states, and by the NGS attempts to build a Geography Alliance network among teaching professionals. The immediate need to redress general geographic illiteracy may have to be instituted indirectly by providing spatially and geospatially relevant alternate ways to examine conventional tasks, problems, and factual information in the context of existing curricula (e.g., in materials included in National Standards for geography, the social sciences, physical and natural sciences, and mathematics).

Although the National Geography Standards (1994) were developed to serve this purpose, there is at present in the US no universally accepted formal structure for introducing age and cognitively appropriate geospatial concepts into formal learning situations (but see an innovative suggestion by Liben 1999). The discipline of geography has several times attempted to provide
such a structure and, specifically, has developed Standards that aim to match age and reasoning capabilities with concept complexity and abstraction (National Geographic Standards: Geography Education Standards Project, 1994). Close examination of these Standards reveals that, while they represented an admirable attempt to formalize geographic thinking at the time, the decade of research and thinking since that time has (naturally) both advanced geographic understanding and pushed the profession’s interests in new directions. Consequently, the nature of geographic knowledge has also changed.

Considering recent developments in the profession, the goal of this article is to speculate about the structure of a scope and sequence framework that will encourage and develop geospatial thinking, thus contributing to two commonly accepted goals of the profession: (1) to enhance geospatial thinking and (2) to help reduce geographic illiteracy. Some thoughts are offered on a sequenced geospatial concept lexicon that may provide an avenue for pursuing these objectives. In a K-12 educational context, for example, it can be suggested that a concept-based structure may be an appropriate entrée for many teachers (regardless of disciplinary specialization) to learn about and use fundamental geospatial concepts in problem and task-related situations with which they are already familiar (refer back to Table 1 for examples of familiar everyday spatial and geospatial tasks). In the long run, this research argues that such a structure used in K-6 environments at the very least could provide an avenue for learning the necessary knowledge base for understanding the contents of many of the existing geotechnical support packages (e.g., educationally oriented GIS software) that may be appropriately introduced in later school and collegiate years. The framework proposed herein provides an opportunity for students and teachers alike to experience the low-tech antecedents of many of the functions and actions contained in these geographical support systems. It is also suggested that the structure presented herein meets the need of conflating participants into the knowledge base that is important for obtaining enlightened user status for geotechnologies rather than these being taught in a manner that tells which commands to call up in order to process data and consequently analyze it and present the derived information in ways that may not be well-comprehended by student users. We also suggest that the framework proposed could be useful for re-examining and updating the Geography Standards, based as it is on a logical progression of concepts from primitives to those that are complex and highly abstract. Given a general geospatial emphasis that is not necessarily discipline-specific, our suggestions should also allow teachers at various K-12 levels to introduce important geospatial concepts to students in a non-geography context by following a pre-specified, sequential grade and cognitively matched progression of exposure to those geospatial concepts. And, finally, it is assumed that the ultimate aim behind developing such a support system is to establish a knowledge platform that will facilitate a life-long way of spatial thinking.

Suggestions from the Literature Relevant to a Geospatial Task and Concept-Based Learning System
It can be hypothesized that an elemental learning system should include the most direct and indirect derivatives from the primitives that provide the base necessary for the elaborations needed to produce the more difficult, complicated, and complex thinking and reasoning processes that are emphasized in later stages of learning.

Here it is assumed that the initial set of concepts lend themselves to low tech presentation and are suited for incorporation in K-6 levels of educational curricula. In the following, evidence is
presented from existing literature that reinforces a claim that concepts defined in the building blocks of a larger conceptual framework (primitives and direct derivations) can be comprehended by early age children.

Zwaan (2004) suggests that vocabulary develops after perception and actions are experienced. In other words, we perceive and act in an environment, store experiences in long term memory, and later facilitate recall when language terms can be associated with those experiences. It follows that children in particular may have a “wow” experience when, incidentally or intentionally, they connect a word concept with an image or a memory or a perception or action. Such an experience imbibes a word with meaning and facilitates communication about objects and actions.

Geospatial thinking is used extensively in everyday life. This is done in both an egocentric and exocentric way (Sholl 1988). Indeed, spatial thinking generally and geospatial thinking in particular is so embedded in everyday life that it is rarely if ever given the attention (or assumed to have the level of importance) that it richly deserves. So much is taken for granted about the way we live that it does not seem necessary for us to understand HOW and WHY we are able to find our way to school, why and how we learn about our neighborhoods, how we are able to successfully perform activities necessary for life support, what part we play in state, interstate, national, and international commerce and communication, or even how we can catch a fly ball or accurately pass a football or soccer ball and other facets of everyday life which we seem to cope with sometimes in the absence of any specialized or intentionally taught or learned knowledge.

In general, it is accepted that, at times, humans carry out cognitive processing of sensed data without conscious thought. This is often the case when we experience human-environment relations, for humanity has survived through the millennia by adjusting fundamental skills and abilities to ensure survival in the face of known and unknown environmental challenges. Many people are satisfied that they have the knowledge, skills, and abilities to cope with living in a complex human-environment interaction system without having the need for specific teaching of spatial or geospatial thinking and specific exposure to tools and methods for learning concepts and procedures that could facilitate or enhance the way they live in and use natural and built environments.

In geography, Bell (2000) used measures of identity (recognition), location (recall of specific places in an arrangement), and magnitude (differentiation of shapes of different size) in his studies of pre-teenage children’s geospatial abilities. Correctly recalling the number of shapes and correctly choosing correct shapes from a set of randomly mixed shapes were two variables that were critical in showing age related differences between two groups of children (7 years old and 9 years old) in his studies, and between the children and adults. Thus, Bell showed that the youngest group was more liable to make incorrect location and identity choices than were the older children and the adults, and that both younger age groups were significantly different from the adults in terms of these measures. In general, adults performed at a near perfect level in terms of location and identity measures. This appeared to be true regardless of the scale of experimentation, whereas both the younger groups had more difficulty in terms of making correct choice of locations at the desktop spatial scale rather than the geospatial (“real world”) scale of the school playground. Thus, scale becomes an important component in the process of
geospatial concept recognition, implying that real world situations may provide more effective learning environments than smaller area and more abstract settings. Bell (2000) also showed a significant difference in terms of relative recall between seven year olds and nine year olds (e.g., when location recall was examined in the presence or absence of a landmark). The relative location tasks were performed at a significantly higher rate of success by the nine year olds than the seven year olds, but their performance rate was still closer to the seven year olds’ measures than to the measures of adult participants. He also suggested that, by the age of nine (i.e., grade three or grade four), children more effectively understand the concept of frames of reference and have at least a minimal understanding of coordinate systems of reference (i.e., Cartesian coordinate-type reference frames). The assumptions are paralleled by material in the Geometry section of the Mathematical Standards (National Council of Teachers of Mathematics, 2000), which also emphasize the teaching of grids, shapes, and reference systems by Third Grade.

Liben and Downs (2001, 245-246) state: “We believe (and think that data support) the generalization that children of different ages and abilities bring differing concepts and knowledge to the instructional setting. As a consequence, different children take away different lessons (sometimes even confusing or inaccurate ones) from the same instructional activities and materials. We believe, therefore, that it is critical to structure activities and materials in ways that take these age and individual differences into account. We believe that, for very young children, the most important kinds of educational experiences will be those that help build the basic foundations on which later more advanced geographic concepts can be taught.”

The ability to comprehend symbolization, however, develops slowly in early age children. It should be obvious that, if one wishes to learn about and accumulate knowledge about the geospatial domain, then an appropriate vocabulary of geospatial concepts based on real objects rather than abstract ones has to be learnt. This can be taken further by suggesting the same is true for recognizing and learning spatial relations between and among objects. This learning process needs to be guided by the content of existing empirical research that demonstrates how and when significant concepts can be effectively introduced into intentional learning situations. Simultaneously, it can be inferred that without such intentional learning designed to articulate spatial and geospatial concepts and to understand all scales of spatial relations, comprehension develops slowly and incompletely. Thus, development of concept understanding is an important link in the process of comprehending spatial and geospatial knowledge. This argument is reflected in the work of Gregg and Sekeres (2006) who discuss vocabulary development, particularly at the elementary level, and basically describe the intentional/incidental difference in vocabulary development: some words are learned intentionally through instruction and others are learned incidentally through reading, play, television etc. They propose a three-tier instructional model with first tier words consisting of terms that everyone typically knows (from incidental learning); second tier words include words that are typically studied in school (intentional concepts); and third tier words would be those known by experts—technical words with very precise meanings. The authors introduce particular second tier words in various media (activities, lessons, movies, books etc.); these terms are also incorporated in numerous hands-on group exercises that encourage students to become comfortable using the words to describe the processes/patterns they are investigating. The authors propose that geography concepts can be used in literacy materials to both encourage students’ reading/vocabulary abilities as well as to introduce them to the meaning of important geographic concepts. Liben (1999) proposes a six-
stage developmental sequence for acquisition of competencies for understanding external spatial representations (the model has not been formally tested as of yet): referential content (viewer begins to understand the meaning of the representation); global differentiation (viewer can differentiate between the referent and the representation); representational insight (viewer assigns “stand for” meaning to the referent—understanding the symbology of various representation types); attribute differentiation (viewer understands that the representation doesn’t necessarily contain or accurately depict all elements of the referent); correspondence mastery (viewer understands the formal representational and geometric correspondences between representation and referent); and meta-representation (viewer can reflect on different modes of representation, how they are used, how they differ culturally; how different techniques change representation, i.e., different map projections; the representation is a cognitive tool).

Experiencing and Learning Fundamental Geospatial Concepts

- **Identity**

In addition to a plethora of historically important psychological research (e.g., Acredolo (1977, 1981; Huttenlocher 1968; Huttenlocher, Hedges and Duncan 1991; Huttenlocher and Newcombe 1984; Huttenlocher, Newcombe, and Sandberg 1994; Liben 1981, 1982, 1991; Liben, Kastens, and Stevenson 2002; Pick 1978; Pick and Acredolo 1983; Piaget and Inhelder 1967, 1969; and many others), there have been significant contributions by geographers working alone or with psychologists (e.g., Blaut, McCleary, and Blaut 1970; Blaut, Stea, Spencer, and Blades 1997; Sowden, Stea, Blades, Spencer, and Blaut 1996; Stea, Blaut, and Stevens 1996; Downs and Liben 1986, 1989, 1993; Doherty, Gale, Pellegrino, and Golledge 1989; and others) who have examined the ability of young children to identify objects in differently scaled spatial situations. While Acredolo and many others have worked with infants and preschoolers, much of the geographers’ works have focused on the ability of preschool and early school aged children to identify symbolic representations of real world environmental phenomena on maps, as well as their more iconic representation on aerial photos. To comprehend maps as representations of real or imaginary worlds, researchers have focused on comprehending map components such as symbolization. For example, research by Liben and Downs (1989) on children’s appreciation of abstract representations of real world objects, Huttenlocher’s (1979, 1994) work on locations, DeLoche’s (1995, 1998) research on symbol recognition, Huntley-Fenner, and Cannon’s (2000) work on magnitude estimation, Bialystok (1992) and DeLoache (1995) suggestions that early age children often regard symbols as objects themselves, and, of course, Piaget’s developmental stages theory, all have dealt with symbol recognition and use by children—an important base for topics such as map reading. The Liben and Downs work asserts that even young children (K-3) can understand symbols and recognize that multiple occurrences of the same symbol does not imply an exact repetition of the original object represented by a single symbol at different locations (i.e., a block may indicate a house, but differently located blocks do not represent the same house). DeLoache, Uttal, and Pierrouatskos (1998) argue that children’s symbol learning develops slowly and that symbol recognition is more likely to occur when symbols represent real objects rather than abstract ones. But all assume or agree that object recognition (i.e., identification) begins shortly after birth. Objects appear first as single phenomena. Later, feature recognition (e.g., size, color) develops and can be used to help differentiate objects, one from another.
In addition to symbol recognition, extensive research by psychologists has examined the development of verbal skills in young children. Again, drawing some examples from an extensive literature, we reference the classic research of Spencer and Darvizeh (1981) who found that preschool children’s verbal descriptions of environmental settings were terse and were insufficient to aid them in developing an understanding of how the spatial information embedded in a particular environment could be comprehended and communicated. Consequently, object/feature identification by children of four years of age suffered from a lack of an appropriate vocabulary. Thus, even if a symbol or object was identified or recognized by children (e.g., by selecting pictures of phenomena), often they did not have the verbal skills to articulate the name or label of the phenomena. This phenomena has recently been re-emphasized by Zwaan (2004) and others.

- **Location**

In the earliest moments of life, we begin to experience the concept of location. Considerable research has been undertaken on children from shortly after birth to the end of pre-school, aimed at determining what spatial and geospatial concepts appear to be comprehended/used. One major theme in this research is that of location recall. This is a spatial skill that is evident in all stages of the human life cycle from infancy to old age (although senility and Alzheimer’s disease may negatively affect this skill). An abundance of theory and empirical studies fall within this general thematic area. Powerful location memory and recall models have included Kosslyn’s model of categorical and coordinate spatial relations (1987), Hirtle and Jonides’ hierarchical model (1985), Huttenlocher, Newcombe and Sandberg’s categorical model (1994), Lansdale’s hybrid model of absolute location (1998), McNamara and LeSueur’s theories of spatial and non-spatial hierarchical organization (1989), and Golledge’s anchor point theory (1978). Empirical research has examined location recall with respect to framed and unframed spaces, relative and absolute locational systems, grid-based coordinate systems, egocentric and allocentric memory, and studies of orientation and wayfinding (Pick and Acredolo 1983; Piaget and Inhelder 1967; Roberts and Aman 1993; Bell 2000; Montello 1998; Tversky 1981, 2005; and many others). Location recall studies have been examined at various scales, in idiosyncratic spaces with varied layouts, number of experimental locations, mode of learning, type of reference frame, and orientation (for a recent overview of this literature, see Bell 2000).

With respect to very young children, Newcombe and Huttenlocher and their associates (1992, 1998) have demonstrated direct recall of the spatial location of single objects by children as young as 16 months. For example, Huttenlocher, Newcombe, and Sandberg (1994) and Newcombe, Huttenlocher, Drummey, and Wiley (1998) show that children as young as 16 months of age can determine object location within a single space (e.g., a sandbox) in which an object is first seen and then hidden. Presumably, this skill does not disappear with ageing (until, probably, senility is reached). They also argue that older children can deal with more complex subdivisions of a space and thus improve their ability to recall spatial locations. Children who are four to six years old were able to subdivide a rectangle on a piece of paper, but were unable to mentally subdivide a larger, real world rectangle (such as a sandbox) in which an object was hidden. This appears to be recognition of the difference between the geospatial concepts of relative location and absolute location, as well as of the fundamental geospatial concept of regionalization.
In an earlier study, Acredolo (1977) showed that five year old children could find a previously learned location without the aid of landmarks, but that three and four year old children required the presence of landmarks and a bounded space (frame of reference) in order to recall location accurately. Herman (1986) also examined the difference between Kindergarten and third grade children’s ability to recall locations in a room-sized space. Different structured spaces were used, including those that could be walked through versus those that could only be viewed, and experimental designs varied, including some that used different types of layouts (a model town versus an array of toys) in which an object’s location was learned and recalled. Newcombe and Huttenlocher (1992) also provided evidence that children of four years of age can solve perspective problems in the near/far fields but not in the right/left fields, while five year olds can accomplish this latter task. Thus, while location can be specified at an early age, associated spatial relations derived from the location concept may not be so identified until some years later.

- **Magnitude**
  Experiments using different sized objects that require recognition of the property of magnitude indicate that the concept of magnitude is understood easily at the pre-school level. Real world examples abound as young children recognize size differences in siblings and adults, or between toys and the objects they replicate (e.g., a toy car and a real car). Magnitude becomes at times a difficult concept if, say, pictures represent real objects (e.g., an ant and an elephant) but are drawn as the same sized objects. With preschool students, much of the discussion of magnitude understanding is based in the task of differentiating numerosity vs. object characteristics (e.g., the number of objects versus the amount of area that the objects occupy). Early studies have shown that even preschool students can make magnitude judgments (e.g., Starkey & Cooper 1980; Antell & Keating 1983; Strauss & Curtis 1981), but there is a question of whether the assumed knowledge of magnitude as numerosity was confounded by area. Huntley-Fenner & Cannon (2000) found that performance in numerosity comparisons was not predicted by verbal counting ability—which seems to imply that magnitude knowledge is more innate than counting knowledge. Rousselle, Palmers and Noel (2004) show results that indicate that surface area was used as the basis for magnitude judgments, not number of objects, at least with preschool students, and these results were apparently in line with results from other studies by Mix (1999) and Brannon and Van de Walle (2002) who found that, when the tasks required numerical processing, only the children with high levels of counting knowledge performed well.

- **Space-Time**
  Elementary comprehension of space-time is evidenced simply by recognition of presence and absence of an object at a specific location at successive time intervals. Captured in spatial ability tasks in terms of recalling if a specific object or feature could be perceived at one time, removed from sight, and placed correctly at the original location at a future time, this concept is often included implicitly rather than explicitly in task scenarios. Measures record the successful recall (and, possibly, replacement) of phenomena that occupy a particular location (as in the Huttenlocher and Newcombe [1984] sandbox experiments). In terms of being able to select appropriate previously perceived objects from a mixed set, then arranging them in a pattern experienced at a previous time period, the work of geographer Bell (2000) is relevant. Thus, any spatially related recall task—whether it be of word lists of spatial concepts or locational arrangements—in part illustrates the space-time trace of environmental or imaged phenomena.
Conceptualizing and Testing a Concept Framework

At this stage we conceive, justify, and pursue the process of building and testing a geospatial concept based scope and sequence framework (i.e., a coordinated and hierarchically organized set of relational concepts—see Boehm 2002), using a selection of teaching aids such as task oriented scenarios that will enable geospatial thinking and reasoning by able-bodied and disabled groups alike. The aim is to select and evaluate elementary geospatial relational concepts (i.e., those that could be introduced prior to and during the third grade and continue to be developed and built on by the 6th grade) and then use them in a coordinated way. Thus, an original emphasis can be placed on primitives and derivatives that include spatial prepositions and prepositional phrases such as on, off, above, below, near, far, next to, against, here, there, and so on (see Landau & Jackendoff 1993). The eventual goal of such a process is to:

- Enable geospatial thinking by providing a case-based learning environment to lay the foundations for the accumulation of geospatial knowledge.
- Facilitate geospatial knowledge transfer based on concept recognition and fundamental geospatial reasoning processes.
- Lay the foundations for a modular add-on support system that can increment knowledge acquisition and geographic understanding as one advances through the K-12 curriculum.

The Basic Building Blocks: Primitive Concepts and their Derivatives

To substantially enhance geospatial thinking and reasoning, we hypothesize that there is a need to recognize that geospatial concepts vary substantially in terms of their ability to be comprehended and used. There are, in fact, different levels of complexity that can be illustrated by suggesting a multilevel geospatial task framework for illustrating how simple and uncomplicated concepts can be combined to make sets of more advanced, complicated, and more abstract concepts (i.e., by examining the “inheritance” structure of complex concepts). An inheritance structure assumes that more abstract and complex concepts (“grandparents”) are defined on the basis of less complex or less abstract concepts (“children” and “grandchildren”). For example, “map” is based on a compilation of concepts such as grid, location, symbol, scale, reference frame, legend, node, network, direction, distance, orientation, and so on (see Liben & Downs 2001 for an elaboration of the significance of map representation). These relations and components can be presented as a “concept map” (Gold, 1998). The fundamental premise of this paper is that, until our discipline has a greater understanding of the concept structure that is embedded in the language of geography, we will have difficulty matching what we intentionally teach and what people are able to understand. As an example, previously we suggested that to fully understand the concept of “map” relevant lower-order (simpler) concepts need to be first introduced, making the concept “map” more a higher level learned product than a beginning concept.

As a way of exploring this idea, a five-level task structure is suggested. In conceptualizing such a framework, Nyerges (2006, personal communication) suggested terms to identify levels as Primitives, Simple Concepts, Difficult Concepts, Complicated Concepts, and Complex Concepts.

Level One: Tasks for Primitives

At this level, tasks relating to recognizing, comprehending, manipulating, and using geospatial primitives would provide the structure for learning and thinking. It can be hypothesized that
these would be the first geospatial concepts to be taught. According to the general literature previously reviewed, Primitive concepts can be introduced in a variety of settings and via a wide variety of everyday tasks and activities in K-3 grades. Specifically, tasks relating to Primitives of identity, location, magnitude, and space-time would constitute the critical elements. Often, these can be presented in such a way that is not necessarily only geographic (e.g., via the introduction and explanation of spatial prepositions and prepositional phrases). Specific tasks would relate to concept identification, recognition, learning, comprehension, use, and knowledge transfer (Table 2). Examples of tasks identified for each Primitive in Table 2 include: Identifying/naming objects or features in an everyday environment (physical objects such as buildings, roads, vegetation, topography, drainage, and what Smith and Mark [2001] call “fiat objects” such as neighborhood, home area, city, state, country); classifying and grouping functions such as supermarkets, drug store, take-out, theatre; identifying educational functions (school, middle school, high school, college); recognizing that objects are found or located at specific places (e.g., home, school, shopping, gas station); recognition of various quantities of occurrences at different sites (e.g., 7-11 or discount store or shopping centers; houses versus apartment blocks); temporal use of locations and places (e.g., occupants of school rooms; when to visit parks or beaches); daily activity patterns.

<Table 2>

**Level Two: Tasks for Simple Concepts**

This (Simple) level would consist of tasks relating to identification, comprehension, manipulation, and use of concepts directly derived from the level one primitives. For example, from Identity, can be developed the concept of class or group and the process of classification, as in a Gazeteer. From two or more locations can be derived concepts such as proximity/nearset neighbor, relative distance, arrangement, distribution, relative direction (expressed as spatial prepositions such as near, far, above, below, behind). From Magnitude can be derived Simple Concepts such as relative size or quantity, area, region, boundary, order, numerosity. From Space-Time can be inferred concepts such as sequence, behavior, change, spread, growth. Tasks suited to teaching Simple Concepts might be: tracing a path along a specified feature (e.g., path along a riverbank); recognizing order in a locational grouping of occurrences (such as houses on the same street); recognizing concepts in perceived and observed contexts (e.g., chair below a desk; parking below an apartment; subway or underpass below street level); identifying an intermediate location between two outliers, such as a path between buildings, fence between houses; identifying real and abstract divisional markers (e.g., boundary dividing freeway from housing; post code divisions); recognition of group membership even in a noisy background (e.g., schools as opposed to hospitals or shopping areas in a city); identifying a sharp division between objects or features (e.g., beach as the edge of a land mass); distinguishing different degrees of separation in space (such as next door as opposed to other parts of an urban area); understanding an arrangement based on a specific criteria such as size or distance (e.g., house numbers along a street; highway mileage signs); comprehending relative position, usually in terms of distance (e.g., classroom seating; nearby states); recognition of an area typified by presence of same characteristics (e.g., land areas such as S. California or the Rocky Mountains; or Europe versus Africa); distinguishing properties of objects including regularity or irregularity of outline (such as globes, containers, boxes, paper, animals); understanding relative direction (e.g., pointing; using clock face directions; cardinal directions).
Level Three: Tasks for Difficult Concepts
This level again consists of tasks relating to identification, comprehension, manipulation, and use of concepts derived from combinations of primitives (Level One) and Level Two derivatives. Examples of Difficult concepts might include: Adjacency which can be derived from an arrangement of locations, while cluster can be derived from relative distance and class or group, as can isolated. Edge or boundary can be derived from link and sequence. Grid can be derived from line, locations, and areas; and so on. Tasks for introducing such concepts might include those requiring recognizing closeness in space, such as “next door” or closest elementary school; defining measures of direction by alignment (e.g., degrees) or relation (clock face; pointing of body part or implement); estimating amount of space in an enclosed setting such as sizes of rooms or different shopping areas; determining (by estimation, measurement, or common acceptance) the middle of a spatial set (such as “the center of the city”); recognizing spatial grouping versus dispersion (such as urban versus rural buildings; or a cluster of farm buildings on a photo; allocating an abstract grid reference to a location (x, y, fields); constructing or recognizing a regular geometric reference system; awareness of containment within a boundary (e.g., city; school yard; shopping mall); recognition of an object’s locational distance from others such as farmhouses versus houses in a suburb; estimating or measuring linear distance (numerosity; recognition of units of measurement); recognition of feature continuity (e.g., street network); ability to order neighbors by real or estimated distance and selecting one closest to base (e.g., nearest friend’s home); recognition of arrangement of a distribution (e.g., regular, uniform, irregular); recognizing the outmost edge of an arrangement (e.g., edge of a town; school boundary); recognition of geometric shapes (e.g., circles, triangles, squares, cones); recognizing or constructing a reference frame for determining distance and direction (e.g., walls of a room; grid cells; latitude and longitude).

Level Four: Tasks for Complicated Concepts
This level includes tasks relating to identifying, comprehending, manipulating, transforming, and using derivatives from some combination of each of the previous levels. For example, the concept buffer can be derived from line, boundary, area, proximity; connectivity can be derived from line, network, centrality, linkage; profile can be derived from space-time, existence, line, order sequence; representation can be derived from location, identity, symbolization, grid, reference frame; scale can be derived from relative magnitude, space-time, symbolization, grid, and so on. Tasks include recognizing edges between politically defined entities (e.g., USA and Mexico); building or recognizing a static or dynamic area surrounding a node (e.g., newspaper circulation; marketplace); estimating or determining by measurement the center of forces operating within a distribution (e.g., center of gravity, mean areal center); comprehending linkage in simple and complex forms (e.g., cross streets along an arterial; network membership); recognition of an enclosed elongated area closely associating with direction (e.g., corridor of functions); recognition of stream composition and flow network from upper reaches to stream mouth; estimating or measuring slope; recognition of a constructed cross section, transect, or description of a component of the environment; presenting information at any scale in a spatialized form; comprehending effects that altering the ratio between real and abstract renderings changes spatial relations, such as clustering or dispersal; ability to comprehend a coherent scene; understanding a bird’s eye view of an undulating environment; replacing real features or objects with abstract renderings.
Level Five: Tasks for Complex Concepts
This consists of tasks involving identifying, comprehending, manipulating, transferring, and using concepts resulting from multiple combinations of previous levels and consisting of abstract concepts that are needed in many facets of geospatial thinking and reasoning. Examples include: activity space derived from location, behavior, linkage, space-time, network, angle, adjacency, grid, direction, reference frame, and so on; Central Place that can be derived from location, magnitude, identity, space-time, centrality, hierarchy, linkage, connectivity, representation, reference frame, behavior, and so on; enclave derived from location, identity, area, specialization, boundary, buffer, class or group, region, and so on. Tasks include: constructing or recognizing a set of activities undertaken in a specific time-space context such as daily travel by household members; estimating or measuring the degree of similarity between spatial distributions or representations such as map comparisons; comprehending hierarchical order as in a settlement system; recognizing difference between a set of data and a simplified or generalized representation of it, as in a matrix; comprehending enclosure based on internal similarity and external difference (e.g., of cultural or ethnic groups in an urban area); comprehending spherical as opposed to flat representational distances, as in great circle distances; estimating or calculating values for places between other given places (e.g., intervening opportunities, interpolation); undertaking complex 2-D representational evaluations and correlations; comprehension of abstract political or organizational structure of large scale human environments; comprehending rationale for and process of representing spherical data on a flat sheet, as in a map projection; recognition of remote connectivity, such as wireless communication or satellite based information; recognizing or constructing regions based on social characteristics of people (e.g., families versus singles); comprehending space as reflected in encoded memory as opposed to objective reality, such as in cognitive mapping; recognizing relocations of a representation away from a previously identified focal point; comprehending and recognizing completely artificially created environments and images, as in virtual or hypothetical settings.

Drawing on the preceding conceptualizations and examples and from existing literature (e.g., Albrecht 1995; Golledge, Bell, and Dougherty 1994), it can be suggested that an examination of functionalities contained in a learning and thinking support system such as a Geographic Information System (GIS) would seem to indicate that many of those functionalities would be placed in levels 4 and 5—the more complicated, complex, and abstract ones (refer back to Table 2).

Experiments
Since grade- and cognitively-related differences in ways of thinking spatially have been suggested elsewhere (e.g., Piaget and Inhelder 1967; NRC 2006), this article focuses on levels 1, 2, and 3 and examine a variety of low tech ways to introduce and encourage the growth of geospatial thinking (for examinations of these activities in high school and college contexts see Marsh, Golledge, and Battersby, Forthcoming; Battersby, Golledge, and Marsh 2006).

To illustrate support for this task-based framework and its emphasis on concept-based learning, examples are now offered of how G3 and G6 students deal with Primitive, Simple, and Difficult geospatial concepts, introduced in a sequenced and integrated manner (i.e., “integrated” as in
linked by a concept inheritance structure). In the area of geocognition and the understanding of geospatial relations generally, the relationship between fundamental concepts (Primitives and Simple concepts) and more complex geospatial concepts such as urban growth, diffusion, and map projection have not been well articulated, leaving this a task for ongoing geoeducational research. At this point it should be noted that the research results reported here are but part of a multi-year study using volunteer participants from local schools (including G3, G6, G9-12) and college level undergraduates (but for G9-12 and college level results, see Marsh, Golledge, and Battersby. Forthcoming). This larger study has examined the relative performance of students in a small sample of local classes to comprehend concepts and how the students perform some geospatial tasks. That larger study, as with this one, is exploratory not confirmatory and is based on volunteers rather than a probability sample. The results therefore should not be generalized to a larger student population, but should provide a source of hypotheses and assumptions for such later (and longer term) investigation.

**Sample Tasks for Geospatial Concept Introduction in Grades K-6**

**Identity Task for G-3 and earlier grades**

Figure 1 gives examples of a low-tech identity task that can be used to confirm an hypothesis that the identity capability is present in a child and could be presented in the early school years (K-1). This type of matching of image and concept is often used to introduce vocabulary terms to early age students, and is not limited to the teaching of geography. However, by including some well-recognized geographic objects (see Smith and Mark 2001), a component of geospatial learning can be introduced via this type of experience at an early age.

*<Figure 1>*

**Location Tasks**

According to the general literature and by referring to the US Standards for Mathematics (National Council of Teachers of Mathematics 2006), awareness of both relative and absolute location seems to be well consolidated by the end of the second year of elementary school. In particular, relative location is comprehended very early and does not depend on numerosity ability; in further years, more complex methods of absolute location (e.g., grids, latitude and longitude) give a more precise and abstract idea of absolute location. In particular, the Cornell, Heth, and Broda (1989) and Heth, Cornell, and Alberts (1997) studies show meaningful improvement between the ages of four to six years and 11 to 12 years of age in terms of accurately sensing and accurately recalling specific locations, particularly those representing well-known environmental features such as landmarks. Examples of simple location recall tasks are given in Figure 2.

*<Figure 2>*

**Magnitude**

Tasks focused on magnitude include easily recognizable and abstract feature representation (e.g., ordering children by size; reasoning about geometric shapes). An example is given in Figure 3.

*<Figure 3>*
**Space-Time**
One task to introduce Space-Time in a real-world context would be to have students build a simple timeline of their daily activity patterns or room usage (see Figure 4).

<Figure 4>

**Empirical Evidence of Geospatial Concept Comprehension: The case of G3 and G6**
To provide evidence of student abilities to recognize and use simple geospatial concepts, a series of experiments were undertaken with participants from G3 (using Primitive and Simple concepts) and G3 and G6 (using Primitive, Simple, and Difficult concepts). These experiments are a part of a larger project on spatial thinking that was undertaken with the help of a limited sample of local elementary and high schools. This over-arching study is too lengthy to be reported in a single paper, particularly if results are illustrated and supported by a set of experimental results. Here, however, we do present some experimental results to illustrate the conceptual framework previously presented in this paper in the G3 and G6 context. Evidence of all test results, the basic concept lexicon developed and used in tasks, and other data and analyses can be found at http://www.geog.ucsb.edu/spatialthinking.

**Experiment 1:**
In this experiment, participants in the 3rd grade group only were given a series of tasks tied to particular geospatial concepts (Primitives and Simple concepts). In the first task, participants were given a randomized set of well-recognized daily activities and a day long time profile anchored by “morning,” “mid-day,” and “night.” Participants were asked to create a daily profile of activities from the given activities (refer back to Figure 4).

The task was to order the activities in a probable sequence (e.g., one would not be correct in placing “breakfast” in the late afternoon). The results were judged on four criteria: (1) all activities correctly ordered; (2) activities correctly placed in the a.m. or p.m. segments of the day; (3) activities ordered in an incorrect or random order; and (4) cases where the instructions were not followed. Forty percent placed all activities in the correct half-day period, and 31 percent ordered all activities correctly.

A second Space-Time task was to solve two time/distance questions. First the participants were given a cartoon of a Rabbit and a Turtle located at different origins on a network of paths. A carrot was drawn at a specific location as a destination point. The following questions were investigated:

Question 1: The Rabbit and the Turtle left at the same time, got to the carrot at the same time, but took different paths. Which animal traveled a longer path?
Question 2: How could both animals get to the carrot at the same time if one takes a longer path? Choose one of the following:
   a. the turtle moves faster than the rabbit
   b. the rabbit moves faster than the turtle
   c. both the rabbit and the turtle move at the same speed

Results show that, for Question 1, 75 percent of 3rd graders (n=48) chose correctly. For Question 2 (n=47), only 57 percent answered correctly. These results seem to indicate an ability to use
time and space to solve a simple Space-Time task in a relatively familiar environment (travel paths), but that the reasoning ability needed to answer the second (more difficult) question was not omnipresent.

In another experiment, the emphasis was placed on the concept of location. Participants were G3 students from two classes in local elementary schools (n=45) and were tested on location recall ability. In Part 1 of this experiment, participants were given a diagram (refer back to Figure 2) containing 6 solidly colored squares scattered in a random distribution. Participants were given whatever time they needed to study the diagram to learn the location of the blocks. When satisfied that they knew this, the diagram was hidden from view and the participants were given a sheet of paper containing a blank square of the same size as that originally viewed, and were asked to plot the location of the original blocks on the blank template. Participants were free to use any locating strategy they could develop. The square provided a reference frame to help them organize their location images.

In further expanding this experiment, participants were given a square of the same size as was used in the previous experiment. This time, concepts of magnitude (size and shape) were given along with location. Five shapes (square, diamond, triangle, ellipse, and star) of varying sizes were randomly located in the task environment (Figure 5).

Again, after taking whatever time was required for each participant to learn the location, distribution, and shapes and sizes, the diagram was hidden and a new blank square was presented. To assist the recall problem, this time three size variations of each shape were provided (see bottom section of Figure 5). Participants were required to recall the correct size and shape and then to indicate each occurrence’s correct location within the square. Only two G3 participants attempted this task; all others indicated it was too difficult.

**Experiment 2**

This experiment used tasks from Levels 1, 2, and 3 or the Conceptual Framework. Participants were volunteers from two elementary schools in the local area (i.e., California’s South-Central Coast), and included two classes of 3rd grade students (n=48) and one class of 6th grade students (n=31). Given the limited nature of the participant group, the following results should be considered as exploratory and the study itself may be considered as a pilot study. At this stage, no population based inferences are possible without a more complete and complex sampling procedure. Nonetheless, we feel the results have value and may lead to other examinations of concept-based geospatial teaching.

**Methods**

Tasks conforming to the first three levels of the previously conceptualized 5-level sequenced concept and task framework were developed and given to students in each grade. Participants were initially shown abstract and commonly identifiable diagrams (which we termed “Real World”) of increasing complexity (illustrated as point, lines, and polygons: Figure 6). They were then given the following instructions:
1.

“List all terms that describe the spatial relationships depicted in the diagram.” Mindful of Zwaan’s (2004) advice on the probable lack of relevant vocabulary by third graders, this task was only given to G6 participants.

2.

“Circle (from a given vocabulary list) all the terms that describe the spatial relationships depicted in the diagram” (given to both G3 and G6).

Participants were first given (separately) abstract diagrams (point, line, polygon), then (again separately) the set of diagrams with more commonly identifiable symbolic objects (“Real World”) features.

<Figure 6>

Results

In this experiment, 6th graders demonstrate that, overall, there appears to be no readily discernable difference between their abilities to generate geospatial terms to describe abstract and symbolic-object (“Real World”) diagrams (27 percent and 29 percent respectively for abstract and symbolic-object point data; 30 percent and 31 percent respectively for abstract and symbolic-object line data; and 21 percent and 24 percent respectively for abstract and symbolic-object polygon data). Since these percentages were so close, no measures of statistically significant differences were calculated.

In the second part of this experiment, 3rd grade and 6th grade participants were given the same diagrams as were used in part one accompanied by a list of relational concepts and were asked to circle words relevant to each point, line, and polygon diagram. Table 3 shows the actual number of words circled for each diagram by 3rd graders and 6th graders. These data do not distinguish between “correctly” and “incorrectly” defined words, only the gross totals. One possibility (not investigated) was simply that 6th graders circled more incorrect terms, but even if this is so, the data in Table 3 indicate a greater willingness to relate terms to the diagrams, possibly indicating greater confidence in concept awareness. While again no significant differences were found between the number of words circled for the abstract and symbolic-object diagrams, there were noticeable differences between the average performances of the 3rd graders and 6th graders.

<Table 3>

In addition, there was little correspondence between the number of terms included in the “write” word lists completed by the 6th graders and their circled terms. This seems to indicate that performing the “write” task first did not seem to markedly influence performance on the “circle” task for the 6th graders, and reinforced the idea that 6th graders self-perceived a greater awareness of the terms used.

Further analysis focused on whether the same concepts were used by 3rd graders and 6th graders on each of the point, line, and polygon “word circle” tasks. For the point task, 5 concepts were identified as “correct”; for the line task, 6 concepts were so identified; and for the polygon task, 9 concepts were so identified. Statistically significant differences were found between the number of times each correct concept was used by the two groups (Tables 4, 5, 6 which show
percentages of participants that chose the correct term for both types of point-based diagrams, and significant differences between participant groups).

<Table 4>

<Table 5>

<Table 6>

In the next phase of this experiment, 6th graders only were asked to rank a given set of 10 concepts by perceived complexity. The concepts given to them included two from each level of the 5-tier concept framework. There was a substantial replication by the student rankings of the levels at which the concepts were categorized in the framework, but it should be noted that “location” (presumably interpreted as absolute and not relative location) was rated fairly highly equivalent to the “Difficult” category rather than lower as a Primitive.

Finally, after giving the 6th grade participants the write and circle term experiment, we gave them another experiment in which we explicitly defined a spatial relationship term stating, “Spatial relationship terms are words that describe how two or more objects in space relate to one another. Objects can be point features such as fire hydrants, line features such as streets, or area features such as cities. From the following list, please circle all the terms that could be used to describe all the possible spatial relationships that can exist between two or more objects.” The participants were given a list of terms containing both spatial and non-spatial relationship terms (the non-spatial relationship terms were determined from a previous pilot study of the term generation portion of the abstract/real-world point, line polygon experiment), and the spatial relationship terms on the list varied in complexity. Most of the spatial relationship terms NOT easily identified by 6th graders came from what we would classify as Levels 4 and 5.

<Table 7>

**Experiment 3**

A further experiment given only to G6 students combined concepts of location, grid-cell location referencing, and sequencing of cues between given end locations. On a 4 x 10 grid, a series of locations were identified: school (the start), house (the end) and locations identified as library, Bill’s house, and store were located on the grid at various sites between school and house. All the locations were connected by a path (Figure 7).

<Figure 7>

In this exercise, we required participants to pretend they were traveling between the points marked “SCHOOL” and “HOME.” We asked them to place the stops between school and home in their proper place on the time line on the bottom of the page. Below the network diagram, a line scale anchored by “School” and “Home” was given. The task was to use the path to determine the sequence of stops between school and home, and to locate each stop in the correct location and sequence along this line scale. Results indicate that 70 percent of 6th grade
participants were able to correctly order the cues, but zero percent got the correct metric location of all the cues along with their correct order.

Another experiment used a variation on shape recognition, somewhat following procedures detailed in some psychometric tests of spatial ability (Eliot & Smith, 1983). In this task, 6th grade participants were given a set of shapes and were required to determine which shape could fit completely within another shape (see Figure 3). Both shapes had to be identified. In a follow-up task, participants were given a different set of shapes and were required to indicate the order of the shapes from SMALLEST to LARGEST. Results of the shape tests indicated that only 26.2 percent of participants were able to solve the “shape in shape” problem, while only 23.4 percent were able to correctly order shapes from smallest to largest. Apparently, the combination of different sized shapes and the task of ordering them by magnitude proved to be difficult for the 6th graders, even though our framework would have classified this task only as “Difficult” at most (i.e., combining concepts of magnitude, shape, and sequence).

Discussion
The initial task of this research was to establish a five level concept task framework that we hypothesized could help decide which geospatial concepts could be appropriately taught and learned at different grade levels. The initial conceptualization was supported by a geospatial concept lexicon that was classified into five categories—Geospatial Primitives, Simple geospatial concepts, Difficult geospatial concepts, Complicated geospatial concepts, and Complex geospatial concepts. Upon completion of this exercise, some empirical testing was undertaken to validate the conceptual structure. Selected experiments were undertaken with participation from local elementary schools (G3; G6). The experiments focused on concepts identified as Primitives, Simple, and Difficult in the suggested 5-level Task framework. We assumed that the derivative concept structure of Complicated and Complex concepts would not have yet developed in K-6 grades.

The general literature in developmental psychology, education, and linguistics provided baseline information on the spatial abilities of the first group we tested (G3). Many studies pointed to the lack of a comprehensive recallable vocabulary in children in K-3 age groups, but generally it was agreed (and supported by National Standards in Geography and Mathematics) that K-3 students would have been exposed to the first and second levels of the proposed conceptual framework (i.e., Primitives and Simple geospatial concepts). Those concepts such as identity/name, location, magnitude, and space-time and derivations such as separation, clustering, join, arrangement, order, distance, point, line, polygon (and their many variations), distribution, path, size, shape and so on, should be known by this group. Our experiments with 3rd graders confirmed that only some concepts were known. Experiment 1 was confined to examining if 3rd graders could deal with only the basic primitives, the Simple, and some more Difficult derivations from these bases. Results varied, but in general performance on these specified tasks was successful as was expected. We also found that as concept complexity increased, 3rd grade ability to comprehend and solve geospatial tasks diminished. Experiment 2 showed that while some Simple geospatial concepts were known at the 3rd grade level, there were significant differences between the task-related performances of G3 and G6 participants on selected geospatial tasks of increasing complexity. What was also evident (not surprisingly) was an increase in geospatial concept awareness with grade (as indicated by the “circle word” experiment). This is expected just from
increasingly varied life experiences and formal education associated with spatial and geospatial concepts in other disciplines (e.g., math, science), along with maturation and social and psychological development. What was significant, however, was that the hierarchical nature of the concept and task framework (at least in the initial stages) was supported. Experiments showed increasing awareness of Simple and Difficult concepts with increasing grades. A significant statistical difference between the performance of 3rd graders and 6th graders on different geospatial tasks was hypothesized (as the general literature suggested) and was supported by the results of several experiments.

While the specific results of some of our experiments could have been reasonably well predicted from the general literature, the significance of the results for the second theme of this article is important. We hypothesized that a support system for encouraging geospatial thinking and learning could be implemented by developing a 5-level geospatial concept and task framework. This would be implemented not as a set of software operations requiring teacher and student training (as in suggested use of GIS in the education system), but as a set of low tech (desk-top and field) tasks that would concentrate on Primitives and Simple and Difficult geospatial concepts, leaving the Complicated and Complex concepts for later introduction—possibly in High School via the electronic form of existing GIS software packages. These experimental results supported hypotheses advanced in the NRC Report on Thinking Spatially (2006), wherein a suggestion was made that the introduction of geospatial concepts into elementary schools should be “low tech” followed by higher tech processes (e.g., using GIS) for teaching spatial thinking in high schools and colleges.

From the experiments detailed previously, the following results were obtained:

- “Write” terms: Even 6th grade individuals did not necessarily adequately describe the spatial relationship depicted in the various point, line, and polygon diagrams; instead, they often described the actual objects depicted in the diagram (“giraffes,” “downtown,” “polygons”). This was consistent with other findings such as those by Zwaan (2004).
- “Circle” terms: here there was a definite progression from G3 to G6 in terms of identifying geospatial relational terms, but even at G6 performance was limited, with an emphasis on object recognition rather than recognizing terms that identified spatial relationships.

In the section requiring rank ordering of the difficulty of concepts (restricted to G6) when asked to rank spatial relationship terms according to their perceived complexity, the ordering hypothesized by the concept and task framework was supported. Further examination of the results of the experiments indicated a perceived order of increasing complexity that correlated with the different levels of the proposed conceptualization.

**Conclusions**

- Knowledge of concepts understood at different grade levels informs what tasks can be successfully implemented at different stages in a geospatially based curriculum or (possibly) in a pedagogically oriented GIS software package.
- The proposed conceptual framework appeared to be reasonable for categorizing concepts by degree of complexity, and the suggested categorization for the lower levels seemed to reflect knowledge structures in both 3rd and 6th grade participants.
All participants were able to adequately recognize Geospatial Primitives (identity, location, magnitude, and space-time) but, as concepts derived from the Primitives were examined, there was a deterioration of 3rd grade performance. Sixth graders appeared to comprehend Primitive, Simple, and some Difficult tasks, but, when queried about Complicated or Complex concepts, did not perform well.

It is our position that careful selection of an ordered sequence of geospatial concepts, expressed in a series of paper and pencil or field tasks, could both introduce many relevant geospatial concepts and provide a basis for intentional learning of those and related concepts in formal classroom settings. The order in which concepts are introduced into various grades seems very relevant. Complicated and Complex concepts should not be introduced early in the K-12 program, for there is not (at the early stages) the knowledge basis and vocabulary needed for understanding much of the geospatial domain. While object recognition developed early in a child’s life cycle, spatial relational terms proved increasingly difficult to comprehend as they became more complicated, complex, and abstract.

Obviously, the questions raised and pursued in this article require further investigation. Some of this has been completed by examining comparative performances by 6th grade, 9th – 12th grade, and college students with regard to understanding and using Difficult, Complicated, and Complex geospatial concepts (see Marsh, Golledge, and Battersby forthcoming; Battersby, Golledge, and Marsh 2006). A future study could involve examining documents such as The National Standards for Geography to see if this proposed sequencing of geospatial concepts conforms with or (partially) departs from the scope and sequence suggested by the results of this research.
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<table>
<thead>
<tr>
<th>Micro/Figural (Spatial) Activities</th>
<th>Environmental and Geographic (Geospatial) Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packing a suitcase</td>
<td>Planning a residential development</td>
</tr>
<tr>
<td>Estimating the size of gap in moving traffic while driving</td>
<td>Learning a route to work</td>
</tr>
<tr>
<td>Setting a table</td>
<td>Choosing a residential neighborhood</td>
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<tr>
<td>Estimating proximity</td>
<td>Understanding a World Map</td>
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<tr>
<td>Recognizing shapes by touch</td>
<td>Identifying land forms</td>
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<tr>
<td>Examining a pattern in a microscope</td>
<td>Comprehending the arrangement of settlements</td>
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<tr>
<td>Finding an icon on a screen</td>
<td>Examining river basins</td>
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<tr>
<td>Parking a car in a confined space</td>
<td>Remembering where to deliver newspapers</td>
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<tr>
<td>Safely walking around your house in the dark</td>
<td>Making a map</td>
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<tr>
<td>Catching a bouncing ball</td>
<td>Finding your city on a map</td>
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<tr>
<td>Shooting baskets</td>
<td>Moving to a new (distant) place of residence</td>
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<tr>
<td>Planting a garden</td>
<td>Describing to others where you live</td>
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### Table 2: Five Level Scope and Sequence of Geospatial Concepts

<table>
<thead>
<tr>
<th>Concept Levels</th>
<th>I Primitive</th>
<th>II Simple</th>
<th>III Difficult</th>
<th>IV Complicated</th>
<th>V Complex</th>
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<tbody>
<tr>
<td>Identity</td>
<td>Arrangement</td>
<td>Adjacency</td>
<td>Buffer</td>
<td>Activity space</td>
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<td>Interpolation</td>
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<td>Grid</td>
<td>Scale</td>
<td>Projection</td>
<td>Projection</td>
</tr>
<tr>
<td></td>
<td>Relative Distance</td>
<td>Growth</td>
<td>Surface</td>
<td>Social Area</td>
<td>Social Area</td>
</tr>
<tr>
<td></td>
<td>Shape</td>
<td>Isolated</td>
<td></td>
<td>Subjective Space</td>
<td>Subjective Space</td>
</tr>
</tbody>
</table>
Table 3: Average number of terms chosen by each grade in “circle words” portion of experiment 1.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Point Abstract</th>
<th>Symbolic - Object</th>
<th>Line Abstract</th>
<th>Symbolic - Object</th>
<th>Polygon Abstract</th>
<th>Symbolic - Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd</td>
<td>3.0</td>
<td>5.52</td>
<td>5.31</td>
<td>7.23</td>
<td>6.46</td>
<td>7.75</td>
</tr>
<tr>
<td>6th</td>
<td>8.19</td>
<td>10.87</td>
<td>13.19</td>
<td>14.06</td>
<td>10.58</td>
<td>11.58</td>
</tr>
<tr>
<td>Significance</td>
<td>t(78) = -2.3, p&lt;0.03</td>
<td>t(78) = -2.4, p&lt;0.02</td>
<td>t(78) = -3.2, p&lt;0.01</td>
<td>t(78) = -2.9, p&lt;0.01</td>
<td>t(78) = -2.1, p&lt;0.05</td>
<td>t(78) = -2.1, p&lt;0.05</td>
</tr>
</tbody>
</table>
Table 4: Percentage of G3 and G6 Participants Using Specific Concepts on Point Task

<table>
<thead>
<tr>
<th>Term</th>
<th>Diagram Type</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; Grade</th>
<th>6&lt;sup&gt;th&lt;/sup&gt; Grade</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>Abstract: *</td>
<td>17%</td>
<td>52%</td>
<td>t(78) = -3.3, p&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>21%</td>
<td>61%</td>
<td>t(78) = -3.9, p&lt;0.01</td>
</tr>
<tr>
<td>Clustered</td>
<td>Abstract: *</td>
<td>2%</td>
<td>81%</td>
<td>t(78) = -10.8, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>6%</td>
<td>87%</td>
<td>t(78) = -11.7, p&lt;0.01</td>
</tr>
<tr>
<td>Near</td>
<td>Abstract: *</td>
<td>23%</td>
<td>48%</td>
<td>t(78) = -2.3, p&lt;0.03</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>6%</td>
<td>55%</td>
<td>t(78) = -5.1, p&lt;0.01</td>
</tr>
<tr>
<td>Proximal</td>
<td>Abstract:</td>
<td>0%</td>
<td>3%</td>
<td>t(78) = -1.0, p&lt;0.4</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>0%</td>
<td>13%</td>
<td>t(78) = -2.2, p&lt;0.04</td>
</tr>
<tr>
<td>Together</td>
<td>Abstract: *</td>
<td>2%</td>
<td>35%</td>
<td>t(78) = -3.7, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>10%</td>
<td>71%</td>
<td>t(78) = 6.6, p&lt;0.01</td>
</tr>
</tbody>
</table>

(* = significant at p ≤ .05)
Table 5: Percentage of Participants Using Concepts on Line Task

<table>
<thead>
<tr>
<th>Term</th>
<th>Diagram Type</th>
<th>3rd Grade</th>
<th>6th Grade</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrangement</td>
<td>Abstract: *</td>
<td>13%</td>
<td>71%</td>
<td>t(78) = -6.1, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>13%</td>
<td>68%</td>
<td>t(78) = -5.7, p&lt;0.01</td>
</tr>
<tr>
<td>Connected</td>
<td>Abstract: *</td>
<td>13%</td>
<td>87%</td>
<td>t(78) = -9.6, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>19%</td>
<td>87%</td>
<td>t(78) = -8.2, p&lt;0.01</td>
</tr>
<tr>
<td>Linked</td>
<td>Abstract: *</td>
<td>19%</td>
<td>84%</td>
<td>t(78) = -7.5, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>19%</td>
<td>90%</td>
<td>t(78) = -9.1, p&lt;0.01</td>
</tr>
<tr>
<td>Network</td>
<td>Abstract: *</td>
<td>4%</td>
<td>26%</td>
<td>t(78) = -2.6, p&lt;0.02</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>0%</td>
<td>39%</td>
<td>t(78) = -4.5, p&lt;0.01</td>
</tr>
<tr>
<td>Patterned</td>
<td>Abstract: *</td>
<td>4%</td>
<td>48%</td>
<td>t(78) = -4.7, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic - Object: *</td>
<td>10%</td>
<td>35%</td>
<td>t(78) = -2.6, p&lt;0.02</td>
</tr>
</tbody>
</table>

(* = significant at  p ≤ .05 )
Table 6: Percentage of Participants Using Specific Concepts on Polygon Task

<table>
<thead>
<tr>
<th>Term</th>
<th>Diagram Type</th>
<th>3rd Grade</th>
<th>6th Grade</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arrangement</strong></td>
<td>Abstract: *</td>
<td>13%</td>
<td>35%</td>
<td>t(78) = -2.2, p&lt;0.04</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object</td>
<td>19%</td>
<td>23%</td>
<td>t(78) = -0.4, p&lt;0.7</td>
</tr>
<tr>
<td><strong>Connected</strong></td>
<td>Abstract: *</td>
<td>13%</td>
<td>90%</td>
<td>t(78) = -10.6, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object: *</td>
<td>17%</td>
<td>87%</td>
<td>t(78) = -8.6, p&lt;0.01</td>
</tr>
<tr>
<td><strong>In</strong></td>
<td>Abstract</td>
<td>17%</td>
<td>35%</td>
<td>t(78) = -1.7, p&lt;0.08</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object</td>
<td>27%</td>
<td>16%</td>
<td>t(78) = 1.2, p&lt;0.3</td>
</tr>
<tr>
<td><strong>Inside</strong></td>
<td>Abstract: *</td>
<td>15%</td>
<td>55%</td>
<td>t(78) = -3.9, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object</td>
<td>27%</td>
<td>45%</td>
<td>t(78) = -1.6, p&lt;0.2</td>
</tr>
<tr>
<td><strong>Linked</strong></td>
<td>Abstract: *</td>
<td>13%</td>
<td>61%</td>
<td>t(78) = -4.8, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object: *</td>
<td>27%</td>
<td>77%</td>
<td>t(78) = -5.0, p&lt;0.01</td>
</tr>
<tr>
<td><strong>Over</strong></td>
<td>Abstract</td>
<td>21%</td>
<td>32%</td>
<td>t(78) = -1.1, p&lt;0.03</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object</td>
<td>21%</td>
<td>35%</td>
<td>t(78) = -1.4, p&lt;0.2</td>
</tr>
<tr>
<td><strong>Together</strong></td>
<td>Abstract: *</td>
<td>29%</td>
<td>77%</td>
<td>t(78) = -4.8, p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object: *</td>
<td>37%</td>
<td>74%</td>
<td>t(78) = -4.3, p&lt;0.01</td>
</tr>
<tr>
<td><strong>Under</strong></td>
<td>Abstract</td>
<td>27%</td>
<td>26%</td>
<td>t(78) = 0.1, p&lt;1.0</td>
</tr>
<tr>
<td></td>
<td>Symbolic Object</td>
<td>33%</td>
<td>48%</td>
<td>t(78) = -1.3, p&lt;0.2</td>
</tr>
</tbody>
</table>

(* = significant at \( p \leq .05 \))
Table 7: Geospatial Terms NOT Easily Identified by 6th Graders

<table>
<thead>
<tr>
<th>6th Grade</th>
<th>Concept Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hierarchical: 95%</td>
<td>4</td>
</tr>
<tr>
<td>Proximal: 95%</td>
<td>3</td>
</tr>
<tr>
<td>Peripheral: 90%</td>
<td>4</td>
</tr>
<tr>
<td>Arrangement: 75%</td>
<td>2</td>
</tr>
<tr>
<td>Boundary/Isolated: 75%</td>
<td>3</td>
</tr>
</tbody>
</table>

(Percentages refer to proportion of sample participants NOT choosing these concepts).
Figure 1: Identity Task
Instructions: Match slides with concept by drawing a line between the slides and concept you match with it.

[Note: This task can be made more complicated by requesting a defining word for each slide as a vocabulary test—and by changing from physical objects to more difficult and abstract concepts such as identifying commercial functions or identifying different map projections]
**Figure 2: Simple Location Tasks**

Instructions: Have participant observe a set of randomly spaced blocks for a given time interval. Remove blocks from sight for an equivalent time. Require participant to replace blocks at original location.

[Note: This simple experiment can be made successively more complex as one moves from relative to absolute location comprehension by procedures such as using different colored blocks; using different sized blocks; measuring only relative locational accuracy, as whether or not each block is placed in its original Thiessen polygon; measuring distance and angular accuracy; and so on.]
**Figure 3: Magnitude Tasks**
Instructions: Consider the following sets of figures and answer the question: which figure can be fitted entirely within one of the other figures? Show which two figures you select.

[Note: this experiment can be made more complex by changing from one to two to three dimensional shapes, or as is done in Spatial Ability Testing]
Figure 4: Space-Time Task
Instructions: Have participants construct a timeline of daily activities from a given set of possible activities by drawing a line from an activity to a time slot.

<table>
<thead>
<tr>
<th>Morning: WAKE-UP!!</th>
<th>Draw a line from each activity to where it happens during the day:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dinner</td>
</tr>
<tr>
<td></td>
<td>Afternoon recess</td>
</tr>
<tr>
<td></td>
<td>Getting ready for school</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mid-day: LUNCH-TIME!!</th>
<th>Morning recess</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eat breakfast</td>
</tr>
<tr>
<td></td>
<td>Drive to school</td>
</tr>
<tr>
<td></td>
<td>Getting ready for bed</td>
</tr>
</tbody>
</table>

| Night: BED-TIME!!           | After-school snack                                             |

[Note: this task can be made more complex by introducing ideas from Time-Space budgeting, by adding activity constraints, by limiting travel modes, by moving from an individual to a multi-person household basis, or by requiring more rigidly specified time-slots, as in 15 minute intervals from say 7:00 am to 7:00 pm.]
Figure 5: Multi-Problem Geospatial Task
Study the shape, size, and location of the objects in the image below. On the next page of this packet we will be asking you to recall their exact shapes, sizes, and locations. When you feel that you have learned their shape, size, and location turn to the next page. You will not be permitted to turn back to this page once you have turned to the next page.

[Note: the key at the bottom of this diagram was given on a separate page along with a blank square. Location and size were the test variables. The two parts are shown in the same diagram here for simplicity of illustration. The task can be made more complicated by adding color to shapes, reproducing the test pattern without a key, or ordering the shapes by size, centrality, nearest neighbor, or other properties.]
Figure 6: Geospatial Representations in the form of Points, Lines, and Polygons

Abstract Representations

<table>
<thead>
<tr>
<th>Abstract Representations</th>
<th>Symbolic Object (“Real World”) Representations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td>Between</td>
</tr>
<tr>
<td>Along</td>
<td>Center</td>
</tr>
<tr>
<td>Among</td>
<td>Close</td>
</tr>
<tr>
<td>Apart</td>
<td>Clustered</td>
</tr>
<tr>
<td>Around</td>
<td>Connected</td>
</tr>
<tr>
<td>Arrangement</td>
<td>Far</td>
</tr>
<tr>
<td>Away</td>
<td>In</td>
</tr>
<tr>
<td>Behind</td>
<td>Inside</td>
</tr>
<tr>
<td>Below</td>
<td>Isolated</td>
</tr>
<tr>
<td>Beside</td>
<td>Linked</td>
</tr>
</tbody>
</table>

Word List

Above          Between       Near          Top
Along          Center         Network       Towards
Among          Close          Node          Under
Apart          Clustered      On            Up
Around         Connected      Outside       
Arrangement    Far            Over          
Away           In             Patterned     
Behind         Inside         Peripheral    
Below          Isolated       Proximal      
Beside         Linked         Together      

[Note: Point, Line, and Polygon diagrams were given as separate tasks and are combined here for convenient illustrative display purposes. This task can be made more or less complex by changing more or less commonly-identifiable objects as the data in the representations.]
Figure 7: Sequencing and Shortest Path

[Note: this task can be made more complex by making the network with more nodes and edges, changing to an irregular shape, increasing the number of landmarks to be sequenced, or requiring accurate distance estimates between landmarks.]