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A Conceptual Framework for Facilitating Geospatial Thinking

Reginald Golledge,* Meredith Marsh,* and Sarah Battersby†

*Department of Geography and Research Unit on Spatial Cognition and Choice, University of California Santa Barbara

†Department of Geography, University of South Carolina

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 third-grade and sixth-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: concept lexicon, geospatial, pilot G3-6 experiments, primitives, task-based framework.*

在这篇文章中，我们调查是否可以概念化和发展一个空间的任务基础框架，以协助构建（在学术等级相关的背景下）一个可描述的、有范围和顺序的地理空间思维概念框架。此框架使世界及其活动能更易被我们理解。通过与本地的三年级及六年级学生的研究，我们呈现此研究论点的概念框架和初步的证据。我们认为一个层次概念可以从复杂的基础上萌芽。研究提供先导试验的结果，以说明假设框架的可行性。这项先导试验表明，两个等级的学生对词汇和概念使用有着明显的差别。我们也提供一些佐证概念框架的潜在用途。*关键词：概念词汇，地理空间，G3-6 先导试验，原始的，基于任务的框架。*

En este artículo investigamos si es posible conceptualizar y desarrollar un marco geoespacial basado en tareas con el fin de ayudar a la estructuración (en un contexto relacionado con el grado) de un marco conceptual que pueda ayudar a preparar un vocabulario y una estructura de alcance y secuencia del razonamiento geoespacial que permita que entendamos el mundo y sus actividades. Presentamos nuestro argumento en términos conceptuales, pero ofrecemos evidencia preliminar basada en el trabajo con estudiantes de tercero y sexto grados de la localidad, de que se puede desarrollar una jerarquía de conceptos con base en la complejidad, y presentamos los resultados de experimentos piloto para ilustrar la viabilidad del marco hipotético. Los estudios piloto muestran una clara diferenciación del uso de vocabulario y concepto entre los dos grados muestreados, y proporcionan algunas pruebas del uso potencial del marco conceptual. *Palabras clave: léxico de concepto, geoespacial, experimentos piloto G3-6, primitivos, marco basado en tareas.*

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 article, we present a conceptual framework to support 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 (see Battersby, Golledge, and Marsh 2006; Marsh, Golledge, and Battersby 2007) suggest that the framework can be extended beyond the elementary level to the middle and

high school levels. 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.

Montello (1993) has pointed out that there are several scales for spatial thinking ranging from microscale (e.g., in nanotechnology or microscopic examination), figural (e.g., the “personal space” restricted to the immediate vicinity of the human body), environmental (i.e., 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 Golledge and Stimson 1997) has expanded geographic thinking into both the figural (decision making, attitudes, preferences, emotions, values, and beliefs) and the microlevel (representing and analyzing cognitive maps, place cells), geographers 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 article we use the term “geospatial” to refer to the environmental and geographic scales. This term is in use in the literature of representation and analysis of geographic phenomena, and in the geotechnical domain that has become a focus for 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.

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 level of 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 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. Much of the geographic information contained in an environment, however, lies in the spatial relations among objects and places. Deciphering 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 produc-

Table 1. Micro, figural, environmental, and geographic activities

Micro/figural (spatial) activities	Environmental and geographic (geospatial) activities
Packing a suitcase	Planning a residential development
Estimating the size of gap in moving traffic while driving	Learning a route to work
Setting a table	Choosing a residential neighborhood
Estimating proximity	Understanding a world map
Recognizing shapes by touch	Identifying landforms
Examining a pattern in a microscope	Comprehending the arrangement of settlements
Finding an icon on a screen	Examining river basins
Parking a car in a confined space	Remembering where to deliver newspapers
Safely walking around your house in the dark	Making a map
Catching a bouncing ball	Finding your city on a map
Shooting baskets	Moving to a new (distant) place of residence
Planting a garden	Describing to others where you live

tion of much of our current geographic knowledge (see Golledge 2002; Turner 2002). The approach used here focuses 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 (National Research Council [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, in literature, and even in most sporting activities (NRC 2006). This trend is documented in materials developed for the Center for Spatially Integrated Social Sciences (CSISS, n.d.). In addition, the National Science Foundation (NSF)-funded SPACE Program (Spatial Perspectives for Analysis in Curriculum Enhancement 2004–2006; see SPACE, n.d.) has trained many teachers of social science in understanding geospatial thinking, and the procedures in the Geography Faculty Development Alliance (GFDA) are doing the same thing. There is a strong sentiment emerging that what is needed in the discipline is a clear and concise statement of what today’s geography students should be taught and when they should learn it. This article 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 United States. Even as 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, U.S. students are rated among the world's worst in terms of geographical knowledge (Coyle 2004; and assessment reports by the National Center for Education Statistics 2005). Evidence from the National Assessment of Educational Progress (NAEP) states that, for the United States:

- The majority of U.S. students in grades four, eight, and twelve 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 four and eight (grade four: from 206 [1994] to 209 [2001]; grade eight: from 260 to 262 over the same period; based on a 0–500 NAEP geography scale) and improvement at grade twelve (from 285 to 285).

With respect to the Roper Poll, which focused on young adults eighteen to twenty-four years of age:

- Americans came in second to last, performing just slightly better than their neighbors from Mexico with an average of twenty-three correct responses out of fifty-six 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 one in three 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 U.S. 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, which has diminished the opportunities to teach geography.
- The difficulty of changing school curricula to include more geography.
- The lack of comprehensive training and opportunities for nongeography teachers to gain at least minimal expertise in comprehending geographic concepts and principles, despite the productive efforts of selected programs to train a cross-section of teachers to appreciate geographic ideas (e.g., CSISS, SPACE, GFDA).

Thus, in the United States, 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 also of their country's place in the world at large. The argument developed in this article 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. This belief was fundamental to the formation of two NRC committees—Rediscovering Geography (1997) 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's Committee on Thinking Spatially.

In the general educational system of the United States, 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 space 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 (NGS), the Association of American Geographers, the National Council for Geographic Education (NCGE), the American Geographical Society (AGS), 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 school curricula.

Although the National Geography Standards (Geography Education Standards Project 1994) were developed to serve this purpose, there is at present in the United States no universally accepted formal structure for introducing cognitive- and age-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 from the Geography Education Standards Project 1994). Close examination of these standards reveals that, although 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. As they exist now, the standards do not adequately represent these changes.

Considering recent developments in the profession, the goal of this article is to speculate about the structure of a conceptual framework including scope and sequence of geospatial concepts. This should contribute 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 might 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 to Table 1 for examples of familiar everyday spatial and geospatial tasks). In the long run, our research argues that such a structure used in K–6 environments at the very least could facilitate learning of the necessary knowledge 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. The structure presented herein might also meet the need of conflating participants into the knowledge base that is important for obtaining enlightened user status for geotechnologies, rather than having these taught in a manner that tells which commands to call up to process data then consequently analyze it and present the derived information in ways that may not be well-comprehended by users. We also suggest that the framework proposed could be useful for reexamining 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 nongeography context by following a prespecified, sequential grade and cognitively matched progression of exposure to those geospatial concepts. Finally, it is assumed that the ultimate aim behind conceptualizing 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

Nystuen (1968) first articulated the set of fundamental concepts needed for building a geographic knowledge base. These were direction/orientation, distance, and connectiveness. In the following discussion he also mentioned accessibility, relative position, and site. Some important modifiers relating to the fundamental terms included historical, dimensional, and time–space tensions that influenced the elements and processes of geographic space.

Papageorgiou (1969) revised the Nystuen suggestions and produced a mathematically derived “basis” for geographic knowledge. He argued that Nystuen’s “primitives” or “basis” constituted “the building blocks of a logical calculus” (213) on which a spatial knowledge system could be constructed. Papageorgiou argues that direction, distance, and connectivity did not, by themselves, constitute a valid basis and added point and time as primitives. Using this basis, geographic vocabulary can be developed by deriving new concepts from combinations or elaboration of the primitives.

Golledge (1992, 1995) further modified the Nystuen and Papageorgiou primitives by showing that distance was a derivative, not a primitive, as it could be derived from the existence of two or more points. The term “point” was replaced with location, and a description of quantity—magnitude—was added as a third primitive. Time was expanded to the spatial domain in geographic reasoning. Another fundamental concept needed for differentiating elements in space was also added, the primitive of identity. Thus, identity, location, magnitude, and space–time were offered as primitives, and, as such, are used as the basis for building the multilevel concept framework developed in this article.

Because herein we emphasize only that part of a general framework that applies to grades K–6, the literature surveyed emphasizes the early stage of geospatial learning and relates it to a geographic concept learning environment. It can be hypothesized that an elementary learning system should include both the primitives and the most direct derivatives from the primitives.

Here it is assumed that the initial set of concepts lend themselves to low-tech presentation and are suited for incorporation in all 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 derivatives) can be comprehended by preteenage children.

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 are so embedded in everyday life that they are rarely if ever given the attention (or assumed to have the level of importance) that they richly deserve. 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 with which we seem to cope, sometimes in the absence of any specialized or intentionally taught or learned spatial knowledge.

In geography, Bell (2000) used measures of identity (recognition), location (recall of specific places in an arrangement), and magnitude (differentiation of shapes of different sizes) in his studies of preteenage 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 (seven years old and nine 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 younger groups had more difficulty in terms of making the 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 might provide more effective learning environments than smaller areas 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 four), children more effectively understand the concept of frames of reference and have at least a minimal understanding of coordinate systems of reference. 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 (x,y) reference systems by third grade.

The presence of individual differences and different learning styles, even in young children, has been well

documented in developmental psychology, providing support for our assumptions that an increasingly complex concept framework should guide a curricula-based learning scheme.

Liben and Downs (2001, 245–46) 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.

Recognizing the need to structure learning to account for these differences, Liben (1999) proposes a six-stage developmental sequence for acquisition of competencies for understanding external spatial representations (the model has not yet been formally tested). The systems are 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 does not 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 metarepresentation (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). Because most representations use forms of symbolization to record objects and features we now examine this relevant literature. In doing so, we examine notions of incidental (commonsense) and intentional (deliberately taught) learning.

The ability to comprehend symbolization develops slowly in young children. It should be obvious that, if one wishes to learn about and accumulate knowledge about the geospatial domain, an appropriate vocabulary of geospatial concepts based on real objects rather than abstract ones has to be learned. This can be taken fur-

ther 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. It also can be inferred that without intentional learning designed to articulate spatial and geospatial concepts, to understand symbolization, 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 Zwaan (2004) and Gregg and Sekeres (2006), who discuss vocabulary development, particularly at the elementary level, and basically describe the intentional–incidental difference in vocabulary development: They argue that some words are learned intentionally through instruction and others are learned incidentally through reading, play, television, and so on. 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 and patterns they are investigating. The authors propose that geography concepts can be used in literacy materials both to encourage students’ reading and vocabulary abilities and to introduce them to the meaning of important geographic concepts.

Given the emphasis placed on developing a basis for building a multitiered concept structure for disciplinary learning, in the following sections we present evidence that the primitives we chose are indeed among the earliest concepts relating to the spatial domain, and can be used as a basis for developing a multilevel concept learning system. Thus we now discuss literature relevant to each of the primitives needed to build such a system.

Identity

In addition to a plethora of historically important psychological research (e.g., Piaget and Inhelder 1967,

1969; Huttenlocher 1968; Acredolo 1977, 1981; Pick 1978; Liben 1981, 1982, 1991; Pick and Acredolo 1983; Huttenlocher and Newcombe 1984; Huttenlocher, Hedges, and Duncan 1991; Huttenlocher, Newcombe, and Sandberg 1994; Liben, Kastens, and Stevenson 2002; and many others), there have been significant contributions by geographers working alone or with psychologists (e.g., Blaut, McCleary, and Blaut 1970; Downs and Liben 1986, 1989, 1993; Doherty et al. 1989; Sowden et al. 1996; Stea, Blaut, and Stephens 1996; Blaut et al. 1997 and others) who have examined the ability of young children to identify objects in differently scaled spatial situations. Although Acredolo and many others have worked with infants and preschoolers, much of the geographers' work has focused on the ability of preschool and early school-aged children to identify (i.e., recognize and name) 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 (Huttenlocher and Presson 1979; Huttenlocher, Newcombe, and Sandberg 1994) work on locations, DeLoache's (DeLoache 1995; DeLoache, Uttal, and Pierroutsakos 1998) research on symbol recognition, Huntley-Fenner and Cannon's (2000) work on magnitude estimation, Bialystok's (1992) and DeLoache's (1995) suggestions that young 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 do not imply an exact repetition of the original object represented by a single symbol at different locations (i.e., a block might indicate a house, but differently located blocks do not represent the same house). DeLoache, Uttal, and Pierroutsakos (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. All assume or agree, however, 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 and feature identification by four-year-olds suffered from lack of an appropriate vocabulary. 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 reemphasized 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 preschool, aimed at determining what spatial and geospatial concepts appear to be comprehended and 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 can 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 (1987) model of categorical and coordinate spatial relations, Hirtle and Jonides's (1985) hierarchical model, Huttenlocher, Newcombe, and Sandberg's (1994) categorical model, Lansdale's (1998) hybrid model of absolute location, McNamara and LeSueur's (1989) theories of spatial and nonspatial hierarchical organization, and Golledge's (1978) anchor point theory. 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 (Piaget and Inhelder 1967; Pick and Acredolo 1983; Tversky 1981 2003; Roberts and Aman 1993; Montello 1998; Bell 2000; 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 (1992) and their associates (Newcombe et al. 1998) have demonstrated direct recall of the spatial location of single objects by children as young as sixteen months. For example, Huttenlocher, Newcombe, and Sandberg (1994) and Newcombe et al. (1998) show that children as young as sixteen 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 aging (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 this case, it was assumed that these young children used relative locations (e.g., "near the top left corner of the sandbox"), as some experimental digging around in a segment occurred rather than exact or one-trial finding of the hidden object was the usual mode of operation.

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) 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 vs. an array of toys) in which an object's location was learned and recalled. Newcombe and Huttenlocher (1992) also provided evidence that children four years of age can solve perspective problems in the near-far fields but not in the right-left fields, whereas five-year-olds can accomplish this latter task. Thus, although location can be specified at an early age, associated spatial relations derived from the location concept might 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 preschool 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 a difficult concept if, say, pictures represent real objects (e.g., an ant and an elephant) but are drawn as same-sized objects. With preschool students, much of the discussion of magnitude understanding is based in the task of differentiating numerosity versus object characteristics (e.g., the number of objects vs. the amount of area that the objects occupy). Early studies have shown that even preschool students can make magnitude judgments (e.g., Starkey and Cooper 1980; Strauss and Curtis 1981; Antell and Keating 1983), but there is a question of whether the assumed knowledge of magnitude as numerosity was confounded by area. Huntley-Fenner and 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, arranging them in a previously experienced pattern is an often used task scenario. Any

spatially related recall task—whether it be of word lists, 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 framework with the primary function of facilitating a scope and sequence of geospatial concepts (i.e., a coordinated and hierarchically organized set of relational concepts) as suggested earlier by Liben (1999) and Gregg and Sekeres (2006). Herein we emphasize only three levels of a five-level structure, believing that there are higher level complex and abstract concepts that are more relevant to learning scenarios beyond the sixth grade. 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 sixth 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, etc.; see Landau and Jackendoff 1993), and relational rather than abstract concepts that might require a high level of numerosity for their comprehension and use.

The Basic Building Blocks: Primitive Concepts and Their Derivatives

To enhance geospatial thinking and reasoning, we hypothesize that the general literature suggests 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 have been found to be present in pre-teenage children. We further hypothesize that different concept levels can be defined in terms of the complexity of their relations to the primitives defined earlier. We define this relationship in terms of an inheritance structure that assumes the more abstract and complex concepts (distant generations) are built from a basis of less complex or less abstract concepts. For example, part of Papageorgiou's basis—distance—can be derived from the primitive location. Equating location with the concept of point, distance refers to the intervening space between points. In its relative sense it can be referred

to as proximity and can be specified by spatial prepositions such as near, far, and so on. Thus, distance is a first-order derivative from a primitive. Given two or more locations, the concept of direction can be inferred and again specified in relative terms such as to the right, in front of, or behind. To elaborate these derivatives further, one needs a higher level concept reference frame. To infer this concept one needs some lower concepts such as link, line, or boundary. To attain these, one must assume that point locations can be joined in some way, thus deriving the concept of line (and from the distance concept, length). Another level of complexity can be added drawing on concepts of location, distance, and direction to infer the possibility of a grid. Thus location, line, connections, and reference frame allow such a concept definition. The existence of grid then allows for the concept of representation. If combined with derivatives from the primitive identity (including classification and symbolization), the concept of map can be inferred. Given this concept, more complex ones such as projection, interpolation, or areal associations can be deduced. Beyond this, one might need to combine derivatives from all of the primitives to derive the concept of spatial autocorrelation and other indicators of spatial relations.

Assuming this derivative structure, and using the idea of increasing concept complexity because of the number of prior concepts needed to derive any given concept, we suggest a five-level framework for geospatial concept classification: primitives, simple (or immediate derivatives from the primitives), difficult (requiring combination of primitive and first-order derivatives), complicated (using derived concepts), and complex (requiring combinations of concepts from many or all prior levels). To expand on this framework, examples of tasks that could be used to teach relevant concepts at each level are now offered.

Level One: Sample Tasks for Learning 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 primitives 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. Specific tasks would relate to concept identification, recognition, comprehension, and use. Examples of tasks identified for each primitive in Table 2 include

Table 2. Five-level scope and sequence of geospatial concepts

Concept levels				
I Primitive	II Simple	III Difficult	IV Complicated	V Complex
Identity location	Arrangement	Adjacency	Buffer	Activity space
Magnitude	Class/group	Angle	Connectivity	Central place
Space–time	Direction	Area	Corridor	Distortion
	Distribution	Center	Gradient	Enclave
	Edge	Change	Profile	Great circle
	Order/sequence	Cluster	Representation	Interpolation
	Proximity	Grid	Scale	Projection
	Relative distance	Growth	Surface	Social area
	Shape	Isolated		Subjective space
		Linked		
		Polygon		
		Reference frame		
		Spread		

Note: Sample concepts are arranged alphabetically in each column.

identifying or naming objects or features in an everyday environment (i.e., identifying 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). Some simple derivative concepts can be explained in terms of 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 vs. apartment blocks); temporal use of locations and places (e.g., occupants of school rooms; when to visit parks or beaches); and daily activity patterns.

Level Two: Sample Tasks for Learning 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 gazetteer. From two or more locations can be derived concepts such as proximity or nearest 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, and numerosity. From space–time can be inferred concepts such as sequence, behavior, change, spread, and growth. Tasks suited to teaching simple concepts might include tracing a path along a specified feature (e.g., path along a riverbank), recognizing order in a locational grouping of occurrences (e.g., 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 (e.g., a path between buildings or a 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 landmass), distinguishing different degrees of separation in space (e.g., 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 the presence of the same characteristics (e.g., land areas such as Southern California or the Rocky Mountains, or Europe vs. Africa), distinguishing properties of objects including regularity or irregularity of outline (e.g., globes, containers, boxes, paper, animals), and understanding relative direction (e.g., pointing, using clock face directions, cardinal directions).

Level Three: Sample Tasks for Learning 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, whereas cluster can be derived from relative distance and class or group. Edge or boundary can be derived from area, 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 (e.g., sizes of rooms or different shopping areas), determining (by estimation, measurement, or common acceptance) the middle of a spatial set (e.g., “the center of the city”), recognizing spatial grouping versus dispersion (e.g., urban vs. 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, schoolyard, shopping mall), recognition of an object’s locational distance from others (e.g., farmhouses vs. 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), and recognizing or constructing a reference frame for determining distance and direction (e.g., walls of a room, grid cells, latitude and longitude).

Level Four: Sample Tasks for Learning Complicated Concepts

This level includes tasks relating to identifying, comprehending, manipulating, and using derivatives from some combination of each of the previous levels. For example, the concept of buffer can be derived from line, boundary, area, and proximity; connectivity can

be derived from line, network, centrality, and linkage; profile can be derived from space–time, existence, line, and order sequence; representation can be derived from location, identity, symbolization, grid, and reference frame; and scale can be derived from relative magnitude, space–time, symbolization, grid, and so on. Tasks include recognizing edges between politically defined entities (e.g., United States 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 associated 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 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; and replacing real features or objects with abstract renderings.

Level Five: Sample Tasks for Learning Complex Concepts

This consists of tasks involving identifying, comprehending, manipulating, 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; and 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 the 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 two-dimensional 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 vs. 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; and comprehending and recognizing completely artificially created environments and images, as in virtual or hypothetical settings.

To illustrate the relevance of the suggested framework for geospatial concept learning, a series of experiments with third-grade and sixth-grade students are now examined.

Experiments

Because grade- and cognitively related differences in ways of thinking spatially have been suggested elsewhere (e.g., Piaget and Inhelder 1967; NRC 2006), this section focuses on levels one, two, and three and examines a variety of low-tech ways to introduce and encourage the growth of geospatial thinking (for examinations of students' abilities to comprehend and use higher level concepts in high school and college contexts see Battersby, Golledge, and Marsh 2006; Marsh, Golledge, and Battersby 2007).

To illustrate support for this task-based framework and its emphasis on concept-based learning, examples are now offered of how third-grade and sixth-grade students deal with selected 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 geoeeducational research. At this point it should be noted that the research results reported here are but part of a multiyear study using volunteer participants from local schools (including third grade, sixth grade, and ninth through twelfth grade) and college undergraduates. This larger study has examined the relative performance of students in a small sample of local classes in terms of comprehending concepts and examining 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 global 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 Grade 3 and Grade 6

The tasks selected for the following experiments were selected from a larger set that was developed to coincide with the five levels of the concept framework (to examine this larger set, see www.geog.ucsb.edu/spatialthinking/ [last accessed 23 March 2007]). These latter tasks were classified by members of our research team acting as an expert panel. Specific tasks used in the following experiments were chosen on the basis of simplicity, ease of scoring, and coincidence with well-established procedures found in the relevant literature. Although not duplicating such examples, each experiment conforms to well-established task scenarios.

Identity Task for Grade Three and Earlier Grades.

Figure 1 gives examples of a low-tech identity task that can be used to confirm the 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 young 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.

Location Tasks. According to the general literature and by referring to the U.S. Standards for Mathematics (National Council of Teachers of Mathematics 2000), awareness of both relative and absolute location

Instructions: Match slides with concept by drawing a line between the slides and concept you match with it.



Animal Hill Red Block Building Bicycle Shop Beach

[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 1. Identity task.

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 later 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 eleven to twelve 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. Here we simplify the identity dimension by using a single type of object, colored blocks of equal size, rather than requiring more complex identification of, say, different landmarks.

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

Space–Time. A simple 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).

Empirical Evidence of Geospatial Concept Comprehension: The Case of Grade Three and Grade Six

To provide evidence of student abilities to recognize and use simple geospatial concepts in a grade context,

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.

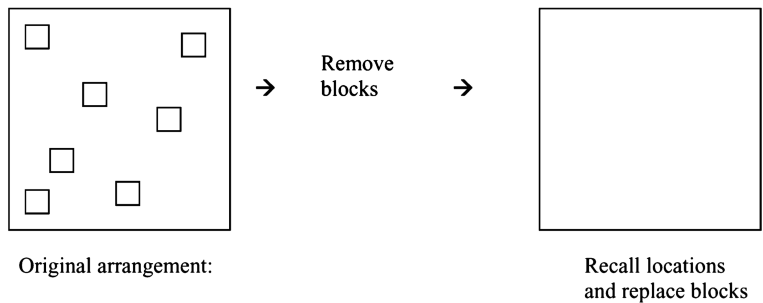


Figure 2. Simple location tasks.

[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.]

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.

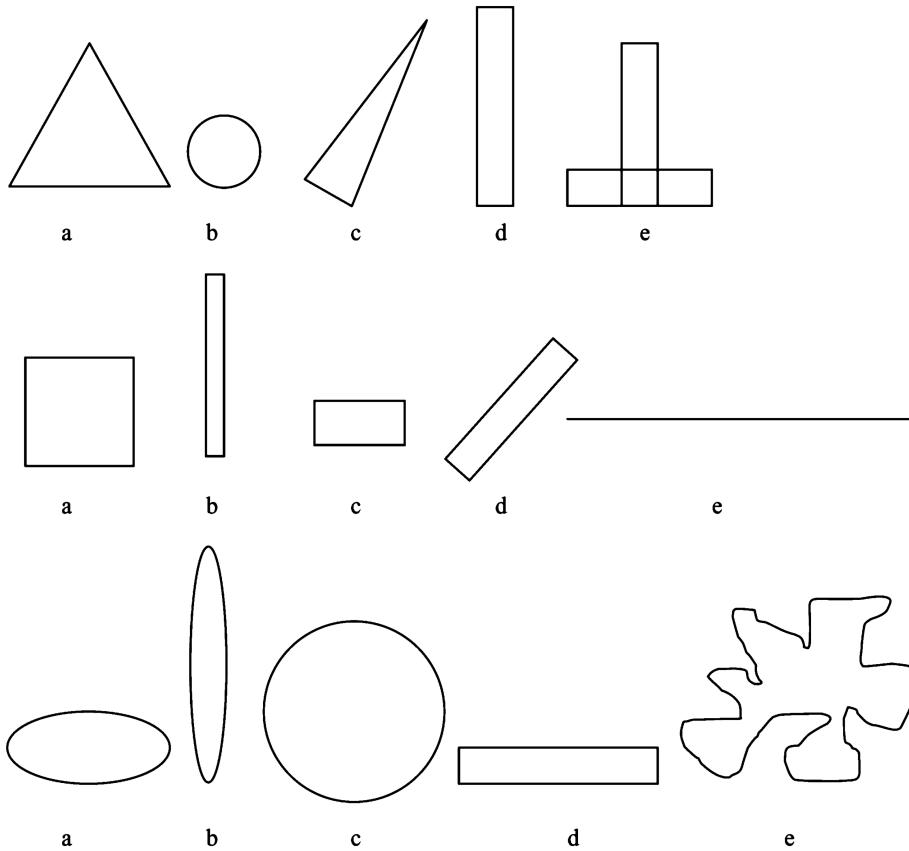


Figure 3. Magnitude tasks.

[Note: this experiment can be made more complex by changing from one to two to three dimensional shapes, or (as is done in some Spatial Ability Testing) by reflecting or rotating the shapes.]

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.

<p>Morning: WAKE-UP!!</p> <ul style="list-style-type: none"> • • • • <p>Mid-day: LUNCH-TIME!!</p> <ul style="list-style-type: none"> • • • • <p>Night: BED-TIME!!</p>	<p>Draw a line from each activity to where it happens during the day:</p> <ul style="list-style-type: none"> Dinner Afternoon recess Getting ready for school Morning recess Eat breakfast Drive to school Getting ready for bed After-school snack
---	---

Figure 4. Space-time task.

[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.]

a series of experiments were undertaken with participants from grade three (using examples of primitive and simple concepts derived from the master list previously referenced) and grades three and six (using examples of primitive, simple, and difficult concepts also derived from the same master list). 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. Here we present some experimental results to illustrate the application of the conceptual framework previously presented in the third-grade and sixth-grade 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> (last accessed 23 March 2007).

Experiment 1

Because we were interested only in differences between grade-level performances, all results are aggregated across all participants in each grade. Although this obscures differences or similarities that might in general provide useful information (e.g., age and sex data) we also realize that teaching is done by grade, and not by differentiating subsets within a grade.

In the first experiment, participants in the third-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 daylong time profile anchored by morning, midday, and night. Participants were asked to create a daily profile of activities from a given list of activities (refer 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). Participants were members of two third-grade classes ($n = 45$) in local schools. 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.

In another experiment, the emphasis was placed on the concept of location. Participants were third-grade students from the same two classes in local elementary schools ($n = 45$) and they were tested on location recall

ability. In Part 1 of this experiment, participants were given a diagram (refer to Figure 2) containing six 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.

To expand 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 the time 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 third-grade participants attempted this task; all others indicated it was too difficult. It seems that concepts requiring integration of several simple concepts are too difficult for these participants.

Experiment 2

This experiment used tasks from levels one, two, and three of 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 third-grade students ($n = 48$) and one class of sixth-grade students ($n = 31$). Again, because we were interested in grade differences and not individual or subset performances, responses were aggregated by grade level. Given the limited nature of the participant group, the following results should be considered exploratory and the study itself can be considered 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 could lead to other examinations of concept-based geospatial teaching.

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.

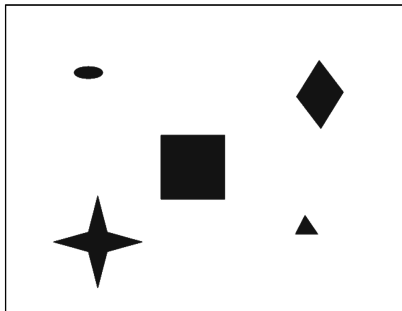
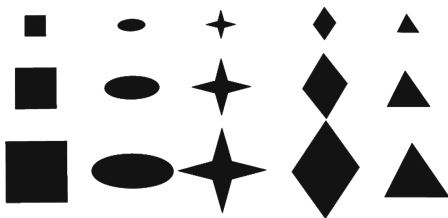


Figure 5. Multi-problem geospatial task.



[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.]

Methods

Tasks conforming to the first three levels of the previously conceptualized five-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 (classified as difficult in our framework and illustrated as points, lines, and polygons; see 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 sixth-grade participants. (The “spatial relatives” concept was defined prior to beginning the task.)
2. “Circle (from a given vocabulary list) all the terms that describe the spatial relationships depicted in the diagram” (given to both third and sixth grade).

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. Herein we examine the frequently mentioned result from the literature that preteenage participants would fare better when dealing with real-world rather than abstract scenarios.

Results

In this experiment, sixth graders demonstrated 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). Because these percentages were so close, no measures of statistically significant differences were calculated. It is interesting that between 70 percent and 75 percent of participants were unable to give suitable spatial relations concepts for any of the point, line, or polygon diagrams.

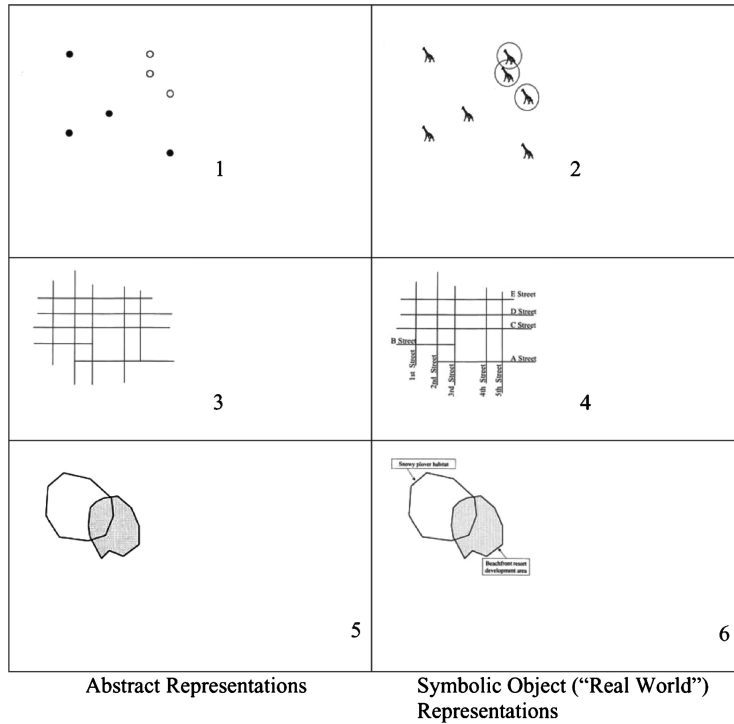


Figure 6. Geospatial representations in the form of points, lines, and polygons.

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.]

In the second part of this experiment, third-grade and sixth-grade participants were given the same diagrams as were used previously, accompanied by a list of spatial relational concepts, and were asked to circle words relevant to each point, line, and polygon diagram. Table 3 shows the average number of words circled for

each diagram by third graders and sixth graders. These data do not distinguish between correctly and incorrectly defined words, only the gross totals. One possibility (not investigated) was simply that sixth graders circled more incorrect terms, but even if this is so, the data in Table 3 indicate a greater willingness to

Table 3. Average number of terms chosen by each grade in “circle words” portion of experiment 1

	Point		Line		Polygon	
	Abstract	Symbolic-object	Abstract	Symbolic-object	Abstract	Symbolic-object
Third grade	3.00	5.52	5.31	7.23	6.46	7.75
Sixth grade	8.19	10.87	13.19	14.06	10.58	11.58
Significance	$t(78) = -2.3,$ $p < 0.03$	$t(78) = -2.4,$ $p < 0.02$	$t(78) = -3.2,$ $p < 0.01$	$t(78) = -2.9,$ $p < 0.01$	$t(78) = -2.1,$ $p < 0.05$	$t(78) = -2.1,$ $p < 0.05$

relate terms to the diagrams, possibly indicating greater confidence in concept awareness by the sixth graders. Again, no significant differences were found between the average number of words circled for the abstract and symbolic-object diagrams, but there were noticeable differences between the average performances of the third graders and sixth graders.

In addition, when we compared results from the two tasks, there was little correspondence between the number of terms included in the writing word lists completed by the sixth graders and their circled terms. This seems to indicate that performing the writing task first did not seem to markedly influence performance on the circling task for the sixth graders, and reinforced the idea that sixth graders self-perceived a greater awareness of the terms used.

Further analysis focused on whether the same concepts were recognized or used by third graders and sixth graders on each of the point, line, and polygon “circle word” tasks. For the point task, five concepts were identified as correct for both groups; for the line task, six concepts were so identified; and for the polygon task, nine 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, and 6, which show percentages of participants that chose the correct term for both types of point-based diagrams, and significant differences between participant groups).

In the next phase of this experiment, sixth graders only were asked to rank a given set of ten concepts by perceived complexity. The concepts given to them included two from each level of the five-tier concept framework. There was a substantial replication by the

Table 4. Percentage of third-grade and sixth-grade participants using specific concepts on point task

		Points		
Term	Diagram type	Third grade	Sixth grade	<i>p</i> value
Close	Abstract*	17%	52%	$t(78) = -3.3, p < 0.05$
	Symbolic-object*	21%	61%	$t(78) = -3.9, p < 0.01$
Clustered	Abstract*	2%	81%	$t(78) = -10.8, p < 0.01$
	Symbolic-object*	6%	87%	$t(78) = -11.7, p < 0.01$
Near	Abstract*	23%	48%	$t(78) = -2.3, p < 0.03$
	Symbolic-object*	6%	55%	$t(78) = -5.1, p < 0.01$
Proximal	Abstract	0%	3%	$t(78) = -1.0, p < 0.40$
	Symbolic-object*	0%	13%	$t(78) = -2.2, p < 0.04$
Together	Abstract*	2%	35%	$t(78) = -3.7, p < 0.01$
	Symbolic-object*	10%	71%	$t(78) = 6.6, p < 0.01$

*Significant at $p \leq 0.05$.

Table 5. Percentage of participants using concepts on line task

		Lines		
Term	Diagram type	Third grade	Sixth grade	<i>p</i> value
Arrangement	Abstract*	13%	71%	$t(78) = -6.1, p < 0.01$
	Symbolic-object*	13%	68%	$t(78) = -5.7, p < 0.01$
Connected	Abstract*	13%	87%	$t(78) = -9.6, p < 0.01$
	Symbolic-object*	19%	87%	$t(78) = -8.2, p < 0.01$
Linked	Abstract*	19%	84%	$t(78) = -7.5, p < 0.01$
	Symbolic-object*	19%	90%	$t(78) = -9.1, p < 0.01$
Network	Abstract*	4%	26%	$t(78) = -2.6, p < 0.02$
	Symbolic-object*	0%	39%	$t(78) = -4.5, p < 0.01$
Patterned	Abstract*	4%	48%	$t(78) = -4.7, p < 0.01$
	Symbolic-object*	10%	35%	$t(78) = -2.6, p < 0.02$

*Significant at $p \leq 0.05$.

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 sixth-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

Table 6. Percentage of participants using specific concepts on polygon task

		Polygon		
Term	Diagram type	Third grade	Sixth grade	<i>p</i> value
Arrangement	Abstract*	13%	35%	$t(78) = -2.2, p < 0.04$
	Symbolic-object	19%	23%	$t(78) = -0.4, p < 0.70$
Connected	Abstract*	13%	90%	$t(78) = -10.6, p < 0.01$
	Symbolic-object*	17%	87%	$t(78) = -8.6, p < 0.01$
In	Abstract	17%	35%	$t(78) = -1.7, p < 0.08$
	Symbolic-object	27%	16%	$t(78) = 1.2, p < 0.30$
Inside	Abstract*	15%	55%	$t(78) = -3.9, p < 0.01$
	Symbolic-object	27%	45%	$t(78) = -1.6, p < 0.20$
Linked	Abstract*	13%	61%	$t(78) = -4.8, p < 0.01$
	Symbolic-object*	27%	77%	$t(78) = -5.0, p < 0.01$
Over	Abstract	21%	32%	$t(78) = -1.1, p < 0.03$
	Symbolic-object	21%	35%	$t(78) = -1.4, p < 0.20$
Together	Abstract*	29%	77%	$t(78) = -4.8, p < 0.01$
	Symbolic-object*	37%	74%	$t(78) = -4.3, p < 0.01$
Under	Abstract	27%	26%	$t(78) = 0.1, p < 1.00$
	Symbolic-object	33%	48%	$t(78) = -1.3, p < 0.20$

*Significant at $p \leq 0.05$.

Table 7. Geospatial terms not easily identified by sixth graders

Sixth grade	Concept level
Hierarchical: 95%	4
Proximal: 95%	3
Peripheral: 90%	4
Arrangement: 75%	2
Boundary/isolated: 75%	3

Note: Percentages refer to proportion of sample participants not choosing these concepts.

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 nonspatial relationship terms (the nonspatial relationship terms were determined from a previous pilot study of the term generation portion of the abstract/real-world point, line, and polygon experiment), and the spatial relationship terms on the list varied in complexity. Most of the spatial relationship terms not easily identified by sixth graders came from what we would classify as levels four and five (Table 7).

Experiment 3

A further experiment given only to sixth-grade students combined concepts of location, grid-cell location referencing, and sequencing of cues between given end locations (i.e., a task that would be rated difficult on

our framework). On a 4 × 10 grid, a series of locations were identified: school (the start), house (the end), and locations identified as library, Bill’s house, and store at various sites between school and house. All locations were connected by a path (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 line on the bottom of the page (i.e., a line scale anchored by School and Home). 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 sixth-grade participants were able to correctly order the cues, but 0 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 and Smith 1983). In this task, sixth-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, and only 23.4 percent were able to correctly order shapes from smallest to largest. Again we see that 75 percent or more of

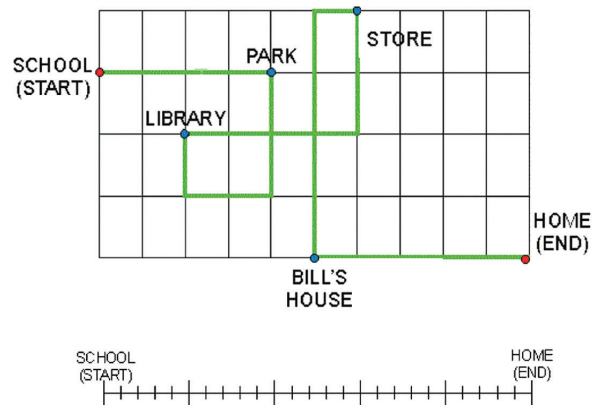


Figure 7. Sequencing and shortest path.

[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.]

the participants could not handle this task. Apparently, the combination of different-sized shapes and the task of ordering them by magnitude proved to be difficult for the sixth graders, even though our framework would have classified this task only as difficult at most (i.e., combining concepts of magnitude, shape, and sequence). Our initial hypothesis that sixth graders should be capable of identifying, recognizing, manipulating, and using the difficult tasks of level three in the framework was (in this case) not supported.

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. After completion of this exercise, some empirical testing was undertaken to validate the conceptual structure. Selected experiments were undertaken with participation from local elementary schools (grades three and six).

The general literature in developmental psychology, education, and linguistics provided baseline information on the spatial abilities of the first group we tested (third-grade students). 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 and 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 third graders confirmed that only some concepts were known, and that their geospatial vocabulary was poorly developed. The first experiment was confined to examining if third graders could deal with only the basic primitives and the simple derivations from these bases. Results varied, but in general performance on the primitives and some simple recall tasks was not as

successful as we expected. As complexity increased only slightly, performance became worse. In particular, the lack of any reasonable geospatial vocabulary was very evident. We also found that as concept complexity increased, third-grade ability to comprehend and solve geospatial tasks diminished. Sixth graders performed the primitive- and simple-level tasks well. Experiment 2 showed that although some simple geospatial concepts were known at the third-grade level, there were significant differences between the task-related performances of third-grade and sixth-grade 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) indicated that even low-level concept recognition and use tasks were not uniformly well done. What stood out was the poverty of participants’ vocabularies with respect to geospatial concepts.

Experiments showed increasing awareness of simple and difficult concepts with increasing grades. A significant statistical difference between the performance of third graders and sixth graders on different geospatial tasks was hypothesized (as the general literature suggested) and was supported by the results of several experiments.

Although 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 five-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 (desktop 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. Examination of related functionalities usually found in GIS software (Albrecht 1995) seems to indicate that most of these would be categorized as complicated or complex in our schema and thus

it would not be reasonable to expect elementary school students to understand, recognize, manipulate, or use them. Perhaps the solution is to undertake research to define a pedagogically oriented “minimal GIS” as suggested by Marsh, Golledge, and Battersby (2007). Our 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 technology 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 sixth-grade students 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) on the absence of comprehensive vocabulary in preteens. At the least, this seems to be the case for the spatial domain.
- “Circle” terms: Here there was a definite progression from third grade to sixth grade in terms of identifying geospatial relational terms, but even at sixth grade performance was limited, with an emphasis on object recognition rather than recognizing terms that identified spatial relationships. Again this points to a lack of knowledge of fundamental geospatial concepts and the need for developing a suitable vocabulary of spatial concepts at an early age.

In the section requiring rank ordering of the difficulty of concepts (restricted to sixth grade) 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

The fundamental premise of this article 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, we suggest that to fully understand the concept of map, relevant lower order (simpler) concepts need to be first introduced, making the concept of map more a higher level learned product than a beginning concept.

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. Although object recognition develops early in a child’s life cycle, spatial relational terms seemed 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 sixth-grade, ninth- through twelfth-grade, and college students with regard to understanding and using difficult, complicated, and complex geospatial concepts (see Battersby, Golledge, and Marsh 2006; Marsh, Golledge, and Battersby 2007). 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 departs from the scope and sequence suggested by the results of this research.

What stands out, even given our restricted experimentation, is that there is a lack of ability to reason geospatially and a lack of a reasonable concept vocabulary in the preteenage groups examined herein.

If we are to combat geospatial illiteracy, immediate and substantial research must be undertaken to determine what knowledge is incidentally obtained and proven useful in comprehending the spatial objects and relations that are embedded in our everyday life. If geography is to be taught and learned effectively in our schools, it must have a creditable and relevant framework to guide such intentional learning. Although the U.S. National Standards in Geography has been such a framework in the past, it is perhaps time to reconsider that framework to test it for validity of the scope and sequence of the concepts contained therein with a view to updating and (as needed) upgrading sections of those standards.

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Correspondence: Department of Geography, University of California, Santa Barbara, Santa Barbara, CA 93106, e-mail: golledge@geog.ucsb.edu (Golledge); meri@geog.ucsb.edu (Marsh); Department of Geography, University of South Carolina, Columbia, SC 29208, e-mail: battersby@sc.edu (Battersby).