ASPECTS OF SPATIAL THINKING IN GEOGRAPHY TEXTBOOK QUESTIONS

A Thesis

by

INJEONG JO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE

August 2007

Major Subject: Geography

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Approved by:

Chair of Committee,	Sarah W. Bednarz
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ABSTRACT

Aspects of Spatial Thinking in Geography Textbook Questions. (August 2007)

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This study examined questions embedded in four high school world geography textbooks to evaluate the degree to which the three components of spatial thinking were incorporated: concepts of space, tools of representation, and processes of reasoning. A three-dimensional taxonomy of spatial thinking to assess the questions was developed and validated via a survey of a group of spatial thinking experts. The spatiality of the concepts featured in 3,010 questions sampled from the textbooks was analyzed. The degree to which spatial representations and stimuli for reasoning were presented was also measured. Every question was compared against the taxonomy and coded. Inter-coder reliability was measured on about one percent of the sample questions.

The results indicated that most questions that required knowledge about spatial concepts could be answered by knowing only simple concepts, such as location and place-specific identity, rather than complex concepts that require the identification of spatial patterns and associations. Not many questions asked students to incorporate spatial representations to answer the questions. Few questions did require creating a new representation. Students were asked to recall memorized geographic knowledge and terms rather than to infer, hypothesize, and generalize. Little difference was found

among the four textbooks in that they rarely integrated the three components of spatial thinking into the questions. The research found that page-margin questions involved aspects of spatial thinking more than section- and chapter-assessment questions. Relatively simple concepts and lower level cognitive processes, however, were required in most questions that integrated the three components.

The development of questions to help students practice complex processes of spatial thinking is necessary. The taxonomy developed in this research can be used as a guide to design curricular, instructional materials, and questions that incorporate aspects of spatial thinking.

DEDICATION

To Jongdoo.

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TABLE OF CONTENTS

LIST OF FIGURES

FIGURE Page

LIST OF TABLES

TABLE Page

TABLE Page

CHAPTER I

INTRODUCTION

Spatial thinking is considered an essential skill to be developed in schools, and more attention is now being paid to how spatial thinking skills can be developed. The tradition of geography emphasizing spatial perspectives and analysis demonstrates its potential as a central subject to foster this important thinking skill. To support spatial thinking in classrooms, however, it should be integrated into the overall education system including instructional practices, curricula and curricular support materials, and assessments.

The geography textbook particularly needs to incorporate aspects of spatial thinking because it not only often represents the curriculum but also forms the basis of instructional activities and assessments. In Texas the number of high school students taking World Geography Studies has increased (Bednarz 2002), and 358,442 students are currently taking the course (Texas Education Agency 2007). Every year, over 350,000 students study with one of the four textbooks approved by Texas Education Agency. Nevertheless, little research has examined the textbooks in terms of aspects of spatial thinking. There are no valid criteria developed which can be used for such examination, either.

The present study evaluated the spatiality of questions posed in four textbooks used in the high school course World Geography Studies in Texas. Over 3,000 questions

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This thesis follows the style of the *Journal of Geography.*

posed in the textbooks were examined in terms of three components of spatial thinking: concepts of space, tools of representation, and processes of reasoning. A taxonomy to assess the selected textbook questions was established from the literature and validated via a survey of spatial thinking experts. Each question was compared against the taxonomy and coded. Descriptive statistic methods, such as frequencies and percentages, were used to summarize and analyze the results. This chapter presents an overview of the research including the context for the study from the literature and the objectives and methodologies of the study.

CONTEXT OF THE STUDY

The term "thinking" is imprecise (Wilson 2000). The study of thinking has been conducted from several perspectives, such as reasoning, judgment and decision making, and problem solving (Holyoak and Morrison 2005). Reasoning emphasizes the process of making inferences from given information, while judgment and decision making have more to do with assessment of values of a choice and the alternatives. Problem solving, on the other hand, represents a course of actions to achieve a goal. These various aspects of thinking, however, are not totally exclusive in that they all require going beyond information given (Bruner 1973). They overlap in many ways as Holyoak and Morrison (2005, 3) wrote:

> To solve a problem, one is likely to reason about the consequences of possible actions and to make decisions to select among alternative actions. A logic problem, as the name implies, is a problem to be solved (with the goal of deriving or evaluating a possible conclusion). Making a decision is often a problem that requires reasoning.

A thinking skill can be defined as "a teachable, partially proceduralized, mental activity that reaches beyond normal cognitive capacities and can be exercised at will" (Smith 2002, 663). Developing thinking skills has been a growing interest in education for decades as societal demands for individuals who are capable of such skills have increased (Nisbet 1993; Resnik 1987). Although there is little consensus on the best way to teach thinking skills (Nisbet 1993), it is well accepted that such skills can be improved through systematic education and that there are various forms of thinking skills that should be fostered. Little doubt does exist that spatial thinking is one of these important thinking skills (Gardner 1999; National Research Council 2006). Empirical research, however, on the development of spatial thinking within school geography is insufficient. Little is known about whether spatial thinking is incorporated into the current geography curriculum, curriculum materials, instructional activity, and assessment. In this section, the definition and major features of spatial thinking on which this study focuses is presented. The need for both evaluation research on the geography textbook in terms of spatial thinking and a taxonomy which can be used for the evaluation is then discussed.

Spatial Thinking as an Area of Expertise

There is no clear consensus about the term "spatial thinking" (NRC 2006) although a similar concept "spatial ability" has often been recognized in the study of cognitive psychology (Golledge and Stimson 1997; Linn and Petersen 1986; Lohman and Nichols 1990; McGee 1979; Montello et al. 1999). Two factors have often been identified as the most common primary dimensions of spatial ability: spatial visualization, which involves mental rotation or manipulation of two- and three-dimensionally presented visual stimuli; and spatial orientation, which represents an ability to comprehend the arrangement of elements within a visual stimulus pattern or to determine how an object or scene will appear when viewed from different perspectives (Lohman and Nichols 1990; McGee 1979; Montello et al. 1999).

However, the most recent study on spatial thinking (NRC 2006) claims that spatial ability is a much more restricted term than spatial thinking, identifying the skill to think spatially as broader sets of interconnected competencies to link space, representations, and reasoning in the process of problem solving. According to the report (NRC 2006), spatial thinking is inseparable from knowledge about space and requires using a variety of spatial concepts, such as direction, distance, destination, and connection to obtain, understand, and communicate that knowledge. Using representations, such as maps, diagrams, charts, and graphs, is an essential part of spatial thinking not only to understand, remember, and communicate about the knowledge of space but also to start complex reasoning. The reasoning process is considered the core of spatial thinking because it enables knowledge about space and representations to be combined for problem solving and decision making, which are the ultimate goals of spatial thinking. In this study, thus, the skill to think spatially is defined as "a collection of cognitive skills comprised of knowing concepts of space, using tools of representation, and reasoning processes" (NRC 2006) rather than as abilities of spatial visualization and spatial orientation.

Not only does spatial thinking prevail in activities of daily life, from knowing how to get to a grocery store, to understanding time zones, and to assembling a piece of furniture, but it also is considered important in today's labor market which values workers capable of using maps, recognizing patterns, and understanding three-dimensional structures more than ever. In addition, the power of spatial thinking is manifested in scientific research, particularly in several disciplines such as astronomy, geology, and physics, as well as geography. The fact that spatial thinking is important for efficacy and success in a variety of contexts is enough to justify the argument that it should be developed in the population through the formal education system. However, spatial thinking has not been instructed (NRC 2006), nor has a consensus been reached on how it can be developed (Lohman and Nichols 1990). At least, researchers seem to agree that learning with spatial representations helps development of spatial thinking skills (Bausmith and Leinhardt 1998; Liben and Downs 2003; Lord 1985; Mathewson 1999; National Research Council 2006; Tversky 2000; Uttal 2000). Despite agreements on the significance of spatial thinking skills and the possibility of developing it through education, empirical research examining whether or not current school subjects address spatial thinking is lacking.

Spatial Thinking and School Geography

Geographers have a long thought that spatial reasoning and spatial representations are distinctive features of the discipline. Although the case that all geographic knowledge is spatial is disputable (Golledge 2002), there is no doubt that the way geographers look at the world and reason is highly spatial. Learning geographic knowledge and geographic reasoning, therefore, may contribute to the development of spatial thinking.

There is a definite emphasis on the spatial perspective in the National Geography Standards: *Geography for Life* (1994). The standards specify that geography contains two key perspectives: the spatial perspective and the ecological perspective. The spatial perspective encompasses inquiry on whereness and an understanding of Earth's spatial patterns and processes; the ecological perspective starts with an understanding of the complex relationships between living and nonliving elements on Earth. The emphasis on a spatial perspective is manifested in one of the Standards six essential elements – The World in Spatial Terms – and three standards suggested under the element: 1) How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information; 2) How to use mental maps to organize information about people, places, and environments; and 3) How to analyze the spatial organization of people, places, and environments on Earth's surface. The standards particularly stress that in learning geography students should be given opportunities to be familiar with a range of spatial concepts and models; to interpret, manipulate, and create a wide variety of spatial representations; and to describe, analyze, and understand the patterns of spatial organization.

However, evidence is insufficient that the expectations regarding the spatial thinking presented in the Standards are implemented into the teacher practices, curricula support materials, and assessments which mostly determine student experiences in the classroom.

The Significance of Textbooks

Reliable evidence on whether the current curriculum incorporates aspects of spatial thinking can be provided from the study of textbooks. Textbooks often represent the curriculum, described as "the statement of curriculum" (Apple 1986, 85) or "a surrogate curriculum" (Venezky 1992, 437). Posner (1992, 5) even described textbooks as "instructional systems," indicating that they not only present the content but also include instructional materials such as teacher guides, study guides or workbooks for students, test items, and so forth. In social studies education in the United States, of which geography is a component, textbooks play a critical role indeed. Literature has recognized that the textbook is the primary source of knowledge to be learned by students (Bednarz 2004b; Garner 1992); the dominant resource on which many social studies teachers rely (Bednarz 2004b; Finkelstein, Nielson, and Switzer 1993; Kragler, Walker, and Martin 2005; Schug, Western, and Enochs 1997); and the instructional material to which most time in the classroom is devoted (Finkelstein, Nielson, and Switzer 1993; Schug, Western, and Enochs 1997). Thus, a thoughtful examination of geography textbooks could be not only an investigation of the knowledge taught in geography but also an examination of teacher practices and student experiences in geography classrooms. However, relatively little research has been conducted on geography textbooks (Bednarz 2002; Bednarz 1997; Stodolsky 1989).

Recall the emphasis on the spatial perspective in the National Geography Standards. If the expectations of the Standards on spatial thinking were fully implemented in geography textbooks, students would be facilitated to think spatially in their experiences working with textbooks, on which they spend most study time. No research has investigated geography textbooks in terms of spatial thinking with one exception. Bednarz (2004b) suggested in her analysis of four world geography textbooks that the textbooks varied significantly in their approaches to spatial thinking, represented by map skills in this study; and that the Standards were not fully implemented into the textbooks despite general improvement over previous editions. The analysis, however, focused on the overall impressions and the introductory material of the textbooks. It is evident that there is a need for more extensive evaluation of various features of the textbooks, including the textual content, visual resources, suggested activities, as well as review questions, in order to determine whether geography textbooks contribute to teaching and learning spatial thinking.

The Role of Questions Posed in Textbooks

Among the various components of the textbook, research has found that there is a considerable relationship between the cognitive level of questions and the level of student thinking (Cole and Williams 1973; Measel and Mood 1972; Newton 1978; Redfield and Rousseau 1981). That is, questions which require students to synthesize, evaluate, and analyze information, or to generate a meaningful relation between phenomena will better facilitate thinking skills than recall questions. It is expected that, as Costa (2001) pointed out, carefully designed questions can cause students to think.

If spatial thinking is to be practiced and learned through working with the textbook, ideally it should be incorporated into these questions as well. Some studies about the nature of questions in science textbooks (Holliday 1981; Leonard 1987; Pizzini, Shepardson, and Abell 1992) exist but none in geography textbooks, particularly in terms of spatial thinking. For this reason, it is worthwhile to analyze questions posed in current geography textbooks to get an insight into whether the current geography textbooks support spatial thinking.

The Need for a Taxonomy of Spatial Thinking

Venezky (1992) pointed out that many textbook studies only provide anecdotal evidence with limited criteria for replication. The research on geography textbooks is not an exception. It is important that a valid and reliable method be used in the analysis, especially to determine whether a new educational goal such as spatial thinking is appropriately incorporated into the textbook.

Use of a taxonomy could help such problems (Bloom et al. 1956). Taxonomy is defined as “a system of classification and the concepts underlying it” (Good 1973), and a taxonomy of educational objectives is defined as “a classification of educational outcomes” (Bloom et al. 1956). Bloom (1956) pointed out that taxonomies not only help teachers and curriculum developers compare the goals of the present curriculum with the range of possible outcomes, plan learning experiences, and prepare evaluation devices, but also serve researchers as criteria for viewing the educational process and analyzing its workings.

Therefore, a taxonomy of spatial thinking, if any, would provide teachers with a guide to implement spatial thinking into instructional practices and assessments; and researchers with a framework to evaluate the current educational activities and materials such as textbooks. Some taxonomies of thinking skills have been developed (Anderson and Krathwohl 2001; Biggs and Collis 1982; Bloom et al. 1956; Costa 2001; Gouge and Yates 2002; Marzano 2001; Moseley et al. 2005; Presseisen 2001; Quellmalz 1987; Stahl and Murphy 1981) but do not seem to be valid to fully address aspects of spatial thinking. There is no valid standard wholly developed for spatial thinking (NRC 2006).

OBJECTIVES AND RESEARCH QUESTIONS

It is widely recognized that geography learning can contribute to the development of spatial thinking, and textbooks are major resources in geography classrooms. However, neither empirical research to provide an analysis of various features of geography textbooks in terms of spatial thinking, nor a valid taxonomy which can be used for such an analysis does exist.

The objective of the research is to investigate how three components of spatial thinking: concepts of space, tools of representation, and processes of reasoning are featured in the questions posed in geography textbooks by (1) establishing a valid taxonomy to assess questions in terms of the three components of spatial thinking and

(2) evaluating questions posed in high school world geography textbooks against the taxonomy.

In order to achieve the objective, two research questions were formulated:

1. How can aspects of spatial thinking be categorized? This question is important to establish a valid taxonomy against which every question is evaluated.
   a. How can concepts of space be categorized?
   b. How can tools of representation be categorized?
   c. How can reasoning processes be categorized?
2. What concepts, tools, and cognitive processes are required to answer the questions posed in the four high school world geography textbooks? This question must be carefully answered to assess whether and to what degree geography textbook questions ask students to think spatially with knowledge about concepts of space, tools of representations, and reasoning processes during answering the questions.
   a. What kinds of concepts are asked in the textbook questions?
   b. Do the questions require students to use or create a spatial representation?
   c. What kinds of cognitive processes are required to answer the questions?
   d. Do the textbook questions integrate the three components of spatial thinking?

METHODOLOGY

Much textbook research uses content analysis, a method in which content is classified by certain coding schemes (Hodson 1999; Krippendorff 2004a; Weber 1985). It is necessary that a framework of spatial thinking be used as a valid coding scheme since this study seeks to analyze textbook questions in terms of aspects of spatial thinking. The present study, thus, has been conducted in two phases: (1) establishing and validating a taxonomy of spatial thinking; (2) analyzing and coding questions contained in the selected textbooks.

For the first phase, I have constructed a taxonomy of spatial thinking based on relevant literature, which can be used to evaluate the spatiality of textbook questions. Three components of spatial thinking identified in the definition of spatial thinking - concepts of space, tools of representations, and processes of reasoning (NRC 2006) - constitute the three primary categories of the taxonomy. The proposed taxonomy has been examined by a panel of experts to determine whether it incorporates complex aspects of spatial thinking; and whether the subcategories are inclusive enough to cover a variety of spatial concepts and cognitive processes which questions might address. The panel was comprised of three faculty members and two graduate students in the Department of Geography at Texas A&M University whose specialty is in spatial thinking and geography education.

In the second phase, questions in the first two units of four high school world geography textbooks were evaluated in terms of three components of spatial thinking. The taxonomy developed in the first phase was used to analyze, classify, and code the questions. The textbooks used in this study are the four high school world geography textbooks currently adopted for use in Texas: *World Geography* (Boehm 2003); *World Geography Today* (Sager and Helgren 2003); *World Geography* (Arreola et al. 2003); and *World Geography* (Baerwald and Fraser 2003). They have almost the same organization and structure: the first unit takes a systematic approach to introduce geographic perspectives, methodologies, and general concepts; and the second and following units take a regional approach presenting details on world regions. The first two units have been selected to compare questions posed in units that differently approach the subject matter of geography – systematically and regionally. Coding was primarily done by the researcher, but about one percent of the sample questions (N = 3,010) were also coded by a panel of experts as a reliability study. The panel participated in one-hour training on question analysis and was given thirty questions randomly sampled from one of the textbooks under study. They coded the questions, and inter-coder agreement (Krippendorff's α) was measured. Finally, descriptive statistics such as frequencies, percentages, and cross-tabulations summarize the characteristics of questions and are used to answer the research questions.

STUDY ASSUMPTIONS

This research begins with several assumptions.

1. My conceptualization of thinking skills, including spatial thinking, is rooted in a cognitive processing view of intelligence, which views intelligence as a skill to be taught and developed.

2. Teachers use textbook questions to encourage students to practice reasoning or problem solving using the knowledge and skills they have learned.
3. Content and forms of questions vary. I assume that a question can be characterized and falls into specific categories by what they require students to know and be able to do.
4. If questions address three components of spatial thinking, they support spatial thinking skills more than those that do not.

STUDY LIMITATIONS

The study has three limitations in data collection and analysis.

1. Selected textbooks are only for a high school level, so the results and discussion of the research may not always apply to K-9 geography education.
2. The amount and level of spatiality of questions may not always be the same as the quality of spatial thinking skills which students can learn through answering those questions. Therefore, spatiality of questions should be interpreted in that light as potential to support spatial thinking rather than guaranteeing students' spatial thinking skills.
3. Inter-coder reliability was relatively low on the concept category probably due to the short training time and insufficient practices.

CHAPTER II

LITERATURE REVIEW

The present research seeks to evaluate the spatiality of questions posed in four high school-level world geography textbooks. This chapter reviews literature relevant to the study. It consists of four sections. In the first section, I review research exploring the nature of spatial thinking that identifies it as an essential skill. I also discuss the potential of geography as a subject to develop students' spatial thinking skills. The second section reviews the role of textbooks in school geography and previous research on geography textbooks. In the third section, I review the role of adjunct questions to facilitate student learning in general and the relationship between the cognitive level of questions and the student level of thinking. The final section explores taxonomies of thinking skills and suggests the need for a taxonomy of spatial thinking which could serve as a basis for teaching and learning spatial thinking.

SPATIAL THINKING

Definition

There has been little consensus on what spatial thinking is (Gersmehl 2006; National Research Council 2006), but research has defined some complementary concepts such as spatial ability, spatial cognition, and spatial intelligence. Among these, spatial ability has most often been conceptualized and discussed. Spatial ability has been defined in many ways (Eliot and Smith 1983) but usually explained by the result of factor analyses on what spatial tests measure (Golledge and Stimson 1997; McGee 1979). It includes abilities such as to mentally rotate objects (visualization) and to comprehend features viewed from a variety of perspectives (orientation). Actually, literature identified these two factors as the most common primary dimensions of spatial ability assessed in most existing psychometric tests (McGee 1979).

Some researchers, however, criticized such definitions of spatial ability in that they are too restricted to encompass a wide range of spatial thinking skills (Caplan, Macpherson, and Tobin 1985; Montello et al. 1999; National Research Council 2006). For example, Montello et al. (1999, 517) pointed out:

> [I]t is unlikely that factors derived paper-pencil tests could account for the entire spectrum of skills that might reasonably be thought to involve "spatial ability" in this more ecologically relevant sense. The restricted definition of spatial ability, as incorporated into many psychometric tests, contrasts with the richness of the general literature on spatial activities and spatial behavior, much of it from disciplines other than psychology.

Golledge and Stimson (1997) also exemplified a list of spatial abilities in addition to visualization and orientation. It includes:

1. The ability to think geometrically.
2. The ability to image complex spatial relations such as three-dimensional molecular structures or complex helices.
3. The ability to recognize spatial patterns of phenomena at a variety of different scales.
4. The ability to perceive three-dimensional structures in two dimensions and the related ability to expand two-dimensional representations into three-dimensional structures.
5. The ability to interpret macro spatial relations such as star patterns or world distributions of climates or vegetation and soils.
6. The ability to give and comprehend directional and distance estimates as required in navigation and path integration activities used in wayfinding.
7. The ability to understand network structures.
8. The ability to perform transformations of space and time.

9. The ability to uncover spatial associations within and between regions or cultures.
10. The ability to image spatial arrangements from verbal reports or writing.
11. The ability to image and organize spatial material hierarchically.
12. The ability to orient oneself with respect to local, relational, or global frames of reference.
13. The ability to perform rotation or other transform tasks.
14. The ability to recreate accurately a representation of scenes viewed from different perspectives or points of view.
15. The ability to compose, overlay, or decompose distributions, patterns, and arrangements of phenomena at different scales, densities, and dispersions.

(Golledge and Stimson 1997, 157)

The most recent research (NRC 2006) on spatial thinking supported such criticisms of psychometric definitions of spatial ability. It made distinctions between spatial thinking and spatial ability by identifying the former as broader sets of interconnected competencies of knowing space, using representations, and reasoning.

In the present research, spatial thinking is defined as "a collection of cognitive skills comprised of knowing spatial concepts, using tools of representation, and reasoning processes," following the definition developed in the report from National Research Council (2006). This conceptualization of spatial thinking is not only broader than spatial ability but it is also applicable to a variety of disciplines including geography.

The Three Components

<u>Concepts of Space</u>

Concepts of space are building blocks for spatial thinking. They make spatial thinking a distinctive way of thinking by using space as a framework for understanding, structuring, and solving problems (NRC 2006). Spatial thinking is inseparable from knowing where something is; what is there; and how it is linked with other places (NRC 2006). Research pointed out that such knowledge about space could be obtained, understood, and communicated more effectively when using spatial concepts (Golledge and Stimson 1997; National Research Council 2006). Golledge and Stimson (1997), for example, emphasized the significance of proper uses of spatial languages for more accurate communications.

> Descriptions of the *what* and *where* of places become more or less interpretable as people choose appropriate nouns and prepositions to formalize relationship (Golledge and Stimson 1997, 414).

A number of spatial concepts can be listed, but some concepts seem particularly relevant to geography: location, distance, direction, connection, movement, distribution, network, pattern, scale, and distance decay. However, there have been few attempts to identify and classify spatial concepts in geography, with a handful of exceptions (Golledge 1995, 2002). Golledge (1995; 2002) defined a set of spatial primitives: place-specific identity, location, magnitude, and time; and derived a series of simple- and complex-spatial concepts from the primitives (Table 1).

Table 1. Concepts of Space (Golledge 1995, 2002)

1995		2002	
First Order Primitives	Identity Location Magnitude Time	Primitives	Place-specific identity Location Magnitude Time
Derived Concepts	Distance Angle and Direction Sequence and Order Connection and Linkage	First Order Concepts	Distribution or Arrangement Frames of reference Orientation and Directions Spatial hierarchies and Dominance
Spatial Distributions	Boundary Density Dispersion Pattern and Shape		
Higher Order Concepts	Correlation Overlay Network and Hierarchy	Higher Order Concepts	Pattern Clustering and Dispersion Spatial association Density and Distance decay

<u>*Tools of Representation*</u>

Representations, either internal or external, serve as an effective tool for thinking and a stimulus to complex reasoning (National Research Council 2006; Tversky 2005). The skill to use and create spatial representations is central to expertise in spatial thinking (NRC 2006). Representations, such as maps, models, diagrams, graphs, and charts, help organizing and externalizing abstract information into more understandable and, therefore, easily communicable forms (Mathewson 1999; Tversky 2005). The significant role of spatial representations as a means for effective communications has been acknowledged not only in the context of daily life but in scientific work as demonstrated by the following quotes.

> Symbolic representations of spatial location, either in linguistic description or in various kinds of visual displays, serve to communicate information gained by one person to other people, saving them the necessity of personally exploring every area they visit (Newcombe and Huttenlocher 2000, 145).

> Scientific work does not become effective science until it is communicated and subjected to public scrutiny. Science and technology develop through the exchange of information and much of this is presented as diagrams, illustrations, maps, plots, schematics, etc., which summarize the information and help others to understand it (Mathewson 1999, 37).

The influence of representations on the facilitation of spatial reasoning has also been recognized. For example, Uttal (2000, 247) wrote:

> Using and thinking about maps may help children to acquire abstract concepts of space and the ability to think systematically about spatial relations that they have not experienced directly. In addition, exposure to maps may help children to think about multiple spatial relations among multiple locations.

Processes of Reasoning

Consider definitions of thinking such as “the mental derivation of mental elements (thoughts) from perceptions and the mental manipulation/combination of these thoughts” (Cohen 1971, 5) and “the mental processing of sensory input and recalled perceptions to achieve a specific end through reasoning, formulating thoughts, and judging” (Beyer, Costa, and Presseisen 2001, 550). Thinking is assumed to be a cognitive process, and reasoning is considered a major cognitive skill (Presseisen 2001). Marzano and Pollock (2001, 31) identified six general reasoning skills from a review of research. The skills include: 1) Identifying similarities and differences; 2) Problem solving and troubleshooting; 3) Argumentation; 4) Decision making; 5) Hypothesis testing and scientific inquiry; and 6) Use of logic and reasoning. Other studies (e.g., Presseisen 2001; Holyoak and Morrison 2005; NRC 2006) also recognized that the reasoning process encompasses cognitive processes such as analyzing, hypothesizing, problem solving, generalizing, and judging.

Processes of reasoning for spatial thinking, therefore, are cognitive processes that enable knowledge about space and representations to be combined for problems solving and decision making through analysis, classification, hypothesis, generalization, and evaluation.

Spatial Thinking as an Essential Skill to be Taught

Tversky (2005) argued that spatial knowledge and spatial inference are critical to survival and that spatial reasoning is ubiquitous. A recent study done by National Research Council (2006), *Learning to Think Spatially*, makes the case that spatial thinking skills are universal and essential in variety of contexts. From knowing how to get to a grocery store, to understanding time zones, and to assembling a piece of furniture, spatial thinking prevails in activities of our daily lives. In addition, spatial thinking is now recognized as an important skill in today's labor market which values workers capable of using real and mental maps, recognizing patterns, and understanding three-dimensional structures more than ever. The power of spatial thinking, in addition, is manifested in its applications to scientific research including astronomy, geology, physics, engineering, and mathematics (National Research Council 2006; Newcombe 2006). Not only is spatial thinking powerful to solve problems requiring management, transformation, and analysis of data (NRC 2006), but also spatial representations, such as diagrams and maps, serve as an effective means of communication through which scientific work can be understood and ideas exchanged (Mathewson 1999; Newcombe 2006).

If spatial thinking is fundamental in our daily life, in the workplace, and in science, it should be a systematic and integral part of the formal education system (Bednarz 2004a; Liben and Downs 2003; Mathewson 1999; National Research Council 2006; Tversky 2005). In practice, however, spatial thinking has been uninstructed in schools (NRC 2006) and not a part of most programs for teacher preparation, either (Mathewson 1999). In addition, as Mathewson (1999) pointed out, subjects such as art, geography, geometry, and science which traditionally emphasize spatial perspectives tend to be marginalized in school curricula.

Spatial Thinking and School Geography

Geography concerns the spatial perspective and analysis. Geographers have long thought that spatial reasoning and spatial representations were distinctive features of the discipline. Pattison (1970) wrote:

> [Major goals of geography are] to describe and explains spatial arrangements – positions, layout, and movement; and to describe and explain the character of places and areas (Pattison 1970, 18).

Golledge (2002) pointed out:

> [Geographic thinking and reasoning] enables us to reveal patterns in spatial distributions and spatial behaviors that may not be obvious to a casual observer in the real world and consequently helps us understand the reasons for occurrences of episodic behaviors in terms of spatial processes (Golledge 2002, 6).

Although the case that all geographic knowledge is spatial is disputable (Golledge 2002), there is no doubt that the way geographers look at the world and reason is highly spatial. Learning how geographers think, therefore, may contribute to learning the way to develop the ability to think spatially. As Greg and Leinhardt (1994) stressed, learning geography can help if students are to develop an ability to think spatially.

One of the most recent efforts in geography education has been to implement the *National Geography Standards: Geography for Life* (1994) into curricula, instructional materials, and assessments. Examining how aspects of spatial thinking are addressed in the Standards would provide insight into how much, if measurable, and how explicitly spatial thinking is incorporated within K-12 geography. The Standards identify two key perspectives of geography: the spatial perspective and the ecological perspective. The spatial perspective encompasses inquiry on whereness and an understanding of spatial patterns and processes on Earth. The ecological perspective starts with an understanding of the complex relationships between living and nonliving elements on Earth. In addition, the Standards identify six essential elements constituting the subject matter of geography: 1) The World in Spatial Terms, 2) Places and Regions, 3) Physical Systems, 4) Human Systems, 5) Environment and Society, and 6) The Uses of Geography. All of the eighteen geography standards, which clarify what students should know and be able to do at the conclusion of three grade levels, are organized around these six essential elements. Emphasis on spatial perspectives is manifested in one of the six essential elements – The World in Spatial Terms – and three standards suggested under the element: 1) How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information; 2) How to use mental maps to organize information about people, places, and environments; and 3) How to analyze the spatial organization of people, places, and environments on Earth's surface. With respect to these three standards, it is particularly urged that in learning geography, students should be given opportunities to be familiar with a range of spatial concepts and models; to interpret, manipulate, and create a wide variety of spatial representations; and to describe, analyze, and understand the patterns of spatial organization. The Standards definitely emphasize the importance of spatial thinking as summarized in the following quote:

> Spatial thinking underpins the intellectual structure of the geography standards…The geography standards demonstrate the possibility and power of infusing spatial thinking into a discipline (NRC 2006, 116).

Nevertheless, there is little evidence that spatial thinking appears in the student experiences in classrooms.

TEXTBOOKS IN THE GEOGRAPHY CLASSROOM

The present research evaluates the spatiality of questions posed in high school-level geography textbooks. Textbooks were chosen because they are ubiquitous not only as part of the student learning experiences but also as a teaching aid (Herlihy 1992; Issitt 2004). This section first discusses the critical role of textbooks in American schools and then specifically in geography classrooms. A review of previous research on spatial thinking featured in geography textbooks follows. In the final, this section points out that more research need to be undertaken to examine the degree to which various components of the textbook, such as suggested activities and review questions, incorporate spatial thinking.

Textbooks in Schools

<u>*A Curriculum*</u>

Curriculum is defined as "the totality of the school experience in the interests of producing and educational effect" (Hlebowitsh 2005, 5). Textbooks often represent the curriculum (Herlihy 1992; Posner 1992), which guides what is to be taught. Stodolsky (1989) pointed out that the major influence of textbooks is to specify topics and content to be covered, which influences the student learning. Apple (1986, 85) argued:

> Whether we like it or not, the curriculum in most American schools is not defined by courses of study or suggested programs, but by one particular artifact, the standardized, grade-level-specific text in mathematics, reading, social studies, science, and so on.

Bednarz (2004b, 223) also noted that textbooks "define the curriculum in lieu of a national curriculum."

Some researchers noted the latent or hidden curriculum that textbooks represent as well. For example, Venezky (1992) described the textbook as a "surrogate curriculum," indicating that textbooks can also influence shaping values, norms, and attitudes of the student. He explained:

> A primary school reader that shows only white, middle-class children in neatly trimmed suburban setting provides a different latent curriculum from a reader with the same stories that mixes races, shows women in traditional male roles, and exhibits a cross-section of housing forms (Venezky 1992, 438).

The Primary Source of Knowledge

The role of textbooks as a vehicle for knowledge acquisition has long been recognized (Chambliss and Calfee 1998; Garner 1992; McMurray and Cronbach 1955). The following quotes note that textbooks are the primary source of knowledge and concepts discussed in classrooms in most school subjects.

> Texts traditionally have provided the student with a wealth of information-the mentioning phenomenon. Students, with the aid of the teacher, are to develop generalizations or conclusions from this data. The text is to serve as a source of base information for this action (Herlihy 1992, 7).

> Textbooks offer students a rich array of new and potentially interesting facts, and open the door to a world of fantastic experiences (Chambliss and Calfee 1998, 7).

An Instructional Tool

Textbooks play a critical role as a major instructional tool. As Mathewson (1999) pointed out, educators depend considerably on textbooks at all levels; and much time in education is spent reading, understanding, and doing activities with materials appearing in textbooks. Textbooks are considered to determine over 70 percent of instructional content and activities in schools throughout the nation (Chambliss and Calfee 1998; Finkelstein, Nielson, and Switzer 1993). Posner (1992) described textbooks as “instructional systems”, meaning that textbooks not only include guides for teachers but also provide the student study guide, test, and a variety of supplementary instructional materials. Venezky (1992) supported such ideas.

> Textbooks provide a limited content expertise for a topic, plus a logical sequencing and a variety of pedagogical supports: activities, questions, test items, and sometimes summaries of expected student difficulties and misconceptions (Venezky 1992, 442).

It seems clear that the textbook is a major tool for teaching and learning in schools (Herlihy 1992).

Textbooks in the Geography Classroom

Relatively very little research has been conducted on geography textbooks (Bednarz 2002; Bednarz 1997; Stodolsky 1989). The role of textbooks in school geography, however, can be inferred from studies on textbooks of social studies, which includes geography as a component. Regarding the role of textbooks in social studies as the source of knowledge and a determinant of the curriculum, Bednarz (2004b) pointed out:

> Textbooks play a critical role particularly in social studies, of which geography is a component… Textbooks set the parameters for knowledge and serve as the source of facts, concepts, and generalizations to be learned by students at each grade level in all parts of the nation (Bednarz 2004b, 223).

This is almost the same as Marran's (1994) point a decade ago:

> The textbook continues to provide the central curricular focus in all subject areas, but especially in the social studies including geography.

The significance of textbooks as a critical instructional tool in social studies classrooms has also been emphasized in the literature (Chall and Connard 1991; Davis et al. 1986; Hill 1994; Marran 1994; Martin 1996; Myers and Savage 2005; White 1985). A survey of social studies teachers done by Shug et al. (1997) revealed that many social studies teachers not only organized their lessons around textbooks but also spent a fair amount of instruction time on activities suggested in the textbook. Many teachers reported that they administered quizzes and tests based on the textbook and had students read and study the content of the textbook. Another survey conducted by Finkelstein et al. (1993) showed similar results in that more than three-fourths of all teachers who participated in their survey used textbooks in their instruction; and that half or more of their instructional time was typically devoted to using the textbook. Acheson (2003) also found in a survey of social studies teachers in Texas that, at each level, an equal or greater number of teachers responded that they used the textbook 'often', 'very often', or 'always', rather than used 'rarely' or 'never'. At the high school level, specifically, nearly 60 percent of teachers used their textbooks regularly. In short, use of textbooks is ubiquitous part of teaching and learning (Herlihy 1992; Issitt 2004).

Spatial Thinking Appearing in Geography Textbooks

As previously mentioned, very little research has been conducted on geography textbooks despite agreements on the importance of textbooks as an essential material used for teaching and learning. Wright (1996) reported that a concern for accuracy of textual content has dominated geography textbook studies. Others have focused on quality of maps and illustrations (Purnell and Solman 1991; Wiegand 2002) or reviewed historical changes of the textbook (Graves 2001; Marsden 2001; Walford 1995).

Few studies examined geography textbooks in terms of aspects of spatial thinking. One exception is Martin's (1996) study assessing the degree to which textbooks implemented the National Standards. It primarily aimed to evaluate the overall organization, content focus, and perspectives of contemporary textbooks against the innovations suggested in geography educational reform efforts, such as *The Guidelines* *for Geographic Education* (Joint Committee on Geographic Education 1984) and *The National Geography Standards*: *Geography for Life* (Geography Education Standards Project 1994). Two criteria of the evaluation are noteworthy in regard to spatial thinking: The World in Spatial Terms and Use of Thematic Maps. Based on a scale of four, the average score of six high school geography textbooks in The World in Spatial Terms criterion was 2.16, which recorded the lowest among the six essential elements (Table 2). Interestingly, however, the textbooks were evaluated highly in terms of their uses of a variety of thematic maps. It could be interpreted that maps are frequently featured but not explicitly linked to the development of spatial thinking skills and perspectives.

Table 2. High School Geography Textbook Evaluation (Martin 1996)

Content Criteria	Average Score
Essential Element 1: The World in Spatial Terms	2.16
Essential Element 2: Places and Regions	2.38
Essential Element 3: Physical Systems	2.44
Essential Element 4: Human Systems	2.89
Essential Element 5: Environment and Society	2.83
Essential Element 6: The Uses of Geography	2.83
The Five Skills of Geography	2.22
Use of Thematic Maps	2.99

In more recent research, Bednarz (2004b) evaluated the degree to which the newest editions of geography textbooks have incorporated the conceptualizations of school geography proposed in the Standards. A close examination of four high school world geography textbooks used in Texas was conducted in terms of their introductory materials presenting a view of the discipline of geography and materials on maps, spatial thinking, and GIS. In regard to the textbooks' approach to map skills, she pointed out:

> All textbooks are richly illustrated with maps, graphs, pictures, and diagrams, but they vary in their instructional approach to map skills…[a textbook gives] nearly no opportunities to make maps or to use them as a means of communication…[another textbook] does not provide the step-by-step instructions (Bednarz 2004b, 235-236).

Both studies definitely inform aspects of spatial thinking appearing in geography textbooks but have limitations too. First, the analyses have made distinction only among textbooks but not within a textbook. Variability could exist in the degree to which each unit, chapter, or feature of a textbook (i.e., suggested activities and review questions) addresses spatial concepts, representations, and reasoning processes. Second, the methodology used in these studies drew much on the experts' insightful scrutiny. Findings of the study are very informative, but the methodologies would hardly be replicated by individual teachers to assess their daily curricula and instructional materials in terms of spatial thinking. There is a need for the research to be able to provide teachers with methodological guidelines and more explicit criteria so that they can use them to incorporate aspects of spatial thinking in their instructional plans, the design of curriculum, and the construction of assessment items. There appears to be no research to deal with such limitations. Moreover, there is no research wholly conducted to assess three components of spatial thinking that might or might not be addressed in contemporary geography textbooks.

QUESTIONS AND LEARNING

It is generally accepted that practice and repeated experiences help a student perform better in certain tasks. Mathewson (1999) pointed out that skills such as understanding and using spatial representations are not automatically acquired. Lord (1985) supported the idea by saying that such skills can be enhanced by using appropriate exercises. Although there are a variety of methods and materials teachers and students use to practice a particular skill, suggested activities and questions posed in textbooks are most representative as materials provided for that purpose. This section considers the role of textbook questions in learning. There have been studies on questions in science and reading textbooks. However, little research exists to this date that examines the questions posed in geography textbooks. Followed by a review of previous studies on textbook questions, this section notes a need for a research to evaluate the degree to which geography textbook questions incorporate spatial thinking.

Effects of Adjunct Questions on Learning

Adjunct questions are questions inserted into instructional materials, such as textbooks, to influence what is learned from the materials (Hamaker 1986). The educational effects and influences of textbook questions may vary, depending on how much and in which way they are chosen and used by individual teachers. It is well known, however, that textbook questions improve students' comprehension of the content (Peverly and Wood 2001); assist students in identifying critical information in the textbook (Holliday 1981); help build strategies for processing given information

(Leonard 1987; Wixson 1983); and stimulate students' problem solving skills (Myers and Savage 2005; Wilen 2001). Early research on adjunct questions has focused on changes in student learning behaviors after being exposed to adjunct questions (e.g., the backward versus forward process). Recent research has been more concerned with different types of questions and different levels of cognitive processes resulting from each type of questions (e.g., verbatim recall versus higher-order problem solving).

Backward and Forward Effects

Rothkopf (1966) observed that questions inserted into textbooks aid student learning of not only the questioned content but also the non-questioned content in the given materials. Supporting Rothkopf's findings through his own experiment, Frase (1967) proposed two models of how questions operate in learning processes: the backward and the forward process.

The backward effect refers to the observation that inserted questions encourage learners to rehearse or repeat previously read content to answer specific questions. As a result, inserted questions enhance performance on identical and similar questions in the future by increasing retention of the information questioned as well as by providing repetitive question-answering practice (Mayer 1975; Rickards and DiVesta 1974). In the backward effect model, students are expected to pay more attention to the information highlighted by questions than other information merely presented in the material. A major concern related to this function of questions, therefore, is that adjunct questions can reduce general learning by directing learners' attention to only a small portion of the material. Wittrock and Lumsdaine (1977) called this "the selective attention model" in that increased retention of questioned information was at the expense of non-questioned information. In regard to this selective attention model, however, Holliday (1981) suggested a complementary idea that adjunct questions can improve student general comprehension of the learning material as well, but only when the questions cover a comprehensive portion of the material.

Questions also have a forward effect in that they guide students to shape appropriate learning strategies to approach materials to which they have not yet been exposed. In this model, questions are considered an intellectual tool to elicit desired learning behaviors by acting as cues (Mayer 1975, 1985) concerning the instructional goals and encouraging the learner to establish a certain performance set of information processing to achieve the goals (Gagné 1973). This performance set based on the cues from the prior questions can be transferred to the acquisition of new materials, so that it facilitates learning and retention of non-asked material as well as material specifically asked about (Wittrock and Lumsdaine 1977). Such a hypothesis implies that questions can be an effective tool to influence students' cognitive activities and, by doing this, to induce desirable learning behaviors from the student in the subsequent learning. Substantial evidence has been provided that adjunct questions maximize learning effectiveness, particularly when learning highly factual materials (Bruning 1968; Frase 1967; McGaw and Grotelueschen 1972; Rothkopf 1966).

Level of Questions and Level of Thinking

While most studies on adjunct questions used the degree to which students recall factual information presented in the material as the measure of effective learning

(Hamaker 1986; Watts and Anderson 1971), some researchers have investigated whether questions can also facilitate higher order learning, such as problem solving skills, critical thinking, and abilities to apply a principle to the new situation. Pointing out that the verbatim recall of factual knowledge is not a common educational goal, what types of questions contribute to facilitating such higher order cognitive skills has been examined (e.g., Watts and Anderson 1971; Felker and Dapra 1975). Research has found that there is a positive relationship between the cognitive level of questions and levels of student thinking (Cole and Williams 1973; Hamilton 1985, 1992; Holliday and Benson 1991; Holliday and McGuire 1992; Measel and Mood 1972; Newton 1978; Redfield and Rousseau 1981). That is, higher order questions to "ask the student to mentally manipulate bits of information previously learned to create an answer or to support an answer with logically reasoned evidence" (Winne 1979) facilitated higher order processing activities, such as integrating and elaborating, more than factual questions, which "ask a learner to repeat or recognize some information exactly as it was presented in instruction" (Andre 1979). For example, Rackards and DiVesta (1974) reported that questions that involved organizing facts under relevant ideas increased overall retention of information more than rote-learning questions. Hamilton (1985) reviewed literature on effects of adjunct questions and demonstrated that many studies supported the idea that factual questions lead to shallow processing such as rehearsal, while higher level questions lead to deeper processing such as inferences.

More interestingly, research has found that higher order questions also facilitated answering other types of questions. That is, they had positive effects on factual test questions as well, whereas factual questions facilitate performance only on repeated or related factual questions. Watts and Anderson's study (1971) showed that students who studied with questions requiring them to apply concepts and principles to new examples demonstrated the best overall performance. Mayer's experimental results (1975) were also consistent with Watts and Anderson's in that learners who were exposed to questions emphasizing a new application of a mathematical model not only excelled on same type of questions but also reasonably good performed on definition and calculating questions. These results indicate that questions whose response requirement is higher facilitate learning in broader and more general way than factual questions (Felker and Dapra 1975; Leonard 1987; Mayer 1975; Myers and Savage 2005; Watts and Anderson 1971; Wilen 2001; Wixson 1983). In addition, questions which demand students to synthesize, evaluate, and analyze the given information, or to generate a meaningful relation between phenomena, will better facilitate thinking skills than memory questions because they cause the learner to produce new knowledge (Hamaker 1986). In sum, students could be helped to develop their comprehension of instructional materials and higher level of cognitive skills by being involved in questions which require them to reflect critical ideas; to explore the relationships between relevant ideas rather than just recall; and to apply them to the new contexts. Some characteristics of questions which could develop higher cognitive activities have been suggested. Such questions require students to:

1. outline the meaning of specific ideas and illustrate their application (often in given contexts);
2. describe or explain the links and relationships between ideas, e.g. within a given generalization or model;

3. demonstrate or evaluate the usefulness of a specific conceptual construct;
4. interpret experience or information by applying relevant ideas;
5. apply cognitive skills to the search for meaning (i.e., tasks which require students to go beyond recall in demonstrating their understanding) (Bennett 2005, 166).

Questions in the Geography Textbook

As Stodolsky (1989) and Kragler et al. (2005) recognized, the most typical social studies textbooks, including geography textbooks, consist of narrative text and sets of questions. Generally, narrative text is read by students and explained by the teacher. Questions usually are to be answered by students as a means of assessing their knowledge of the content. Review questions are interspersed throughout the text and also are at the end of each section, chapter, and sometimes at the end of each unit. Questions designed for skill development, like map and diagram reading skills, appear at the margin of almost every page and supplemental sections. Despite the considerable proportion of questions within the geography text, research analyzing questions posed in geography textbooks and data directly bearing on aspects of spatial thinking in the questions is scanty. Pizzini et al. (1992) examined the cognitive level of questions posed in eight middle school science textbooks and revealed that about 80 percent of the questions examined required students only to recall facts and definitions rather than to apply, analyze, and evaluate information. No such a study has been conducted on questions embedded in geography textbooks.

Questions to Facilitate Spatial Thinking

Spatial thinking requires students to know and remember spatial information and concepts. It also requires students to be able to make sense of the information and flexibly use such knowledge. In other words, spatial thinking requires knowing spatial concepts to structure knowledge of space; utilizing tools of representations to understand, remember, and communicate it effectively; complex reasoning which enables knowledge about space and representations to be combined for problem solving and decision making. Thus, if facilitating spatial thinking is an educational objective, questions designed to achieve the objective should require students not only to understand critical spatial concepts but also to carry out certain cognitive processes relevant to such characteristics of spatial thinking. Using and creating a variety of spatial representations should also be encouraged in these questions.

In addition, if developing spatial thinking skills is a new, yet permanent, goal of geography education, textbook activities and questions should be rich with opportunities to acquire and practice such skills. Empirical research is lacking, however, on whether spatial thinking is supported by these features of textbooks. There is a need to evaluate the merits of these materials to facilitate students' spatial thinking skills. For analysis and evaluation purposes, the need for reliable criteria is evident.

TAXONOMY OF SPATIAL THINKING

Definition and Use of Taxonomy in Education

Taxonomy is defined as "a system of classification and the concepts underlying it" (Good 1973). The Taxonomy of Educational Objectives (Bloom et al. 1956) was defined as "a classification of educational outcomes", and considered "a framework for classifying statements of what we expect or intend students to learn as a result of instruction" (Krathwohl 2002). In this study, taxonomy refers to a theory-based framework of classification, following the classic meaning of taxonomy such as Good's (1973).

Using taxonomies is an effective means to examine instruction and instructional materials to determine where relative emphases are; how curriculum is aligned; and what educational opportunities are missing. Such examinations contribute to the improvement of instructional design, course and lesson planning, and assessments in the future (Anderson and Krathwohl 2001; Bloom et al. 1956; Moseley et al. 2005). Numerous taxonomies have been developed to meet a variety of needs in education. Taxonomies of cognitive processes are particularly of interest to this study because one objective is to design a framework for teaching and learning spatial thinking, a powerful cognitive skill to integrate knowledge of space, tools of representation, and reasoning processes.

Taxonomies of Cognitive Processes

Moseley et al. (2005) recognized, through an extensive review of taxonomies and frameworks of thinking skills in use since the 1950s, that many of the frameworks had features similar to Bloom's (1956) cognitive domains, a three-tier structure of knowledge, basic thinking, and higher order thinking. It was also recognized that all the taxonomies examined included a classification scheme of 'higher order' thinking which roughly corresponds to Bloom's Analysis, Synthesis, and Evaluation categories. An overview of taxonomies that were particularly designed to aid instructional and curriculum design for teaching thinking skills (which is the primary interest of the present research) will inform the design of a spatial thinking taxonomy.

Taxonomies of the Cognitive Domain

The taxonomy most widely known and used in education, developed by Bloom et al., is the Taxonomy of Educational Objectives (1956). Six major categories of the cognitive domain were defined: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Table 3). They were ordered from simple to complex and from concrete to abstract, and a cumulative hierarchy among the domain was assumed. That is, simpler categories were considered prerequisite of more complex categories.

Table 3. Levels of Cognitive Domain (Bloom et al. 1956)

Level	Category	Description
1	Knowledge	The recall of specifics and universals; methods and processes; or a pattern, structure, or setting
2	Comprehension	The lowest level of understanding
3	Application	The use of abstractions in particular and concrete situations
4	Analysis	The breakdown of a communication into its constituent elements or parts such that the relative hierarchy of ideas is made clear and/or the relations between the ideas expressed are made explicit
5	Synthesis	The putting together of elements and parts so as to form a whole
6	Evaluation	Judgments about the value of material and methods for given purposes

A revision of what has become known as “Bloom’s Taxonomy” was done by Anderson and Krathwohl (2001). They recognized that the Knowledge domain in the original taxonomy implied both the cognitive process and the subject matter, while other categories only represented cognitive processes. This anomaly was eliminated in the revision by separating the taxonomy into two dimensions: the knowledge dimension and the cognitive dimension. Since the present study concerned the cognitive process domain, only that dimension was reviewed (Table 4). The category names were changed to verb form, and some of them were renamed (i.e., “comprehension” to “understand”, “synthesis” to “create”).

Table 4. Levels of Cognitive Domain Revised (Anderson and Krathwohl 2001)

Level	Category	Description
1	Remember	Retrieve relevant knowledge from long-term memory.
2	Understand	Construct meaning from instructional messages, including oral, written, and graphic communication.
3	Apply	Carry out or use a procedure in a given situation.
4	Analyze	Break material into constituent parts and determine how parts relate to one another and to an overall structure or purpose.
5	Evaluate	Make judgments based on criteria and standards.
6	Create	Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure.

Marzano (2001) also made an attempt to improve the original Bloom's Taxonomy. This taxonomy consisted of Self-system, Metacognitive System, Cognitive System, and Knowledge Domain; and the cognitive system was defined as the way of information processing used to complete a task. The level of the cognitive system proposed in this taxonomy is illustrated in Table 5.

Table 5. Cognitive System (Marzano 2001)

Level	Category		Description
1	Retrieval	Recall	To identify or recognize features of information but not necessarily to understand the structure of knowledge or not differentiate critical from noncritical components
		Execution	To perform a procedure without significant error but not necessarily to understand how and why the procedure works
2	Comprehension	Synthesis	To identify the basic structure of the knowledge and the critical as opposed to noncritical characteristics
		Representation	To construct an accurate symbolic representation of the knowledge differentiating critical from noncritical elements
3	Analysis	Matching	To identify important similarities and differences between knowledge
		Classifying	To identify superordinate and subordinate categories related to the knowledge
		Error Analysis	To identify errors in the presentations or use of the knowledge
		Generalizing	To conduct new generalization or principles based on the knowledge
		Specifying	To identify specific applications or logical consequences of the knowledge
4	Knowledge Utilization	Decision Making	To use knowledge to make decisions or make decisions about the use of knowledge
		Problem Solving	To use knowledge to solve problems or solve problems about the knowledge
		Experimental Inquiry	To use the knowledge to generate and test hypotheses or generate and test hypotheses about the knowledge
		Investigation	To use the knowledge to conduct investigations or conduct investigations about the knowledge

Stahl and Murphy (1981) argued that the cognitive domains proposed by Bloom are insufficient to explain how people process information when thinking and learning. They defined eight domains of cognition upon which the Stahl Perceptual Information Processing and Operations Model (SPInPrOM), which details a 21-component process explaining how people think and learn, was built. The level and brief description of the eight cognitive domains are shown in Table 6. One distinctive feature of this taxonomy from others is that it includes pre-learning behavior – Preparation.

Table 6. The Domain of Cognition (Stahl and Murphy 1981)

Level	Category	Description
1	Preparation	The mental readiness of the individual immediately before and at the time new information is presented
2	Reception	The reciting of information immediately in front of the individual or recalling information that has recently been presented within the same lesson
3	Transformation	The ways students may alter or change the original information as they try to give it meaning
4	Retention	The recalling from memory of previously learned information and transformations approximately 24 hours after this information was first thought about
5	Transfersion (Applying)	The ability to use information retrieved by long-term memory in specific situations similar to and/or different from those where the information was first practiced
6	Incorporation	The ability to use information in appropriate situations such that its use is automatic and habitual without the student's conscious recall and application of the information
7	Organization	The level whereby students express how they have arranged, organized and/or prioritized their learnings as part of their cognitive-belief system
8	Generation	The ability to produce new sets of rules, principles, guidelines, methods, etc., which represent unique combinations or synthesis of two or more sets of rules, principles, etc., which the student has mastered on the Incorporation level

Presseisen (2001) pointed out that there are many possible taxonomies of thinking skills, and at least five categories are essential (Table 7). The structure is almost the same as the taxonomies presented previously in that cognitive processes, such as recognizing and defining, were considered the simplest; and cognitive processes, such as stating, inferring, and, evaluating, were the most complex.

Table 7. A Taxonomy of Essential Thinking Skills (Presseisen 2001)

	Category	Description	Example
Simple	Qualifying	Finding unique characteristics	Recognizing Defining Gathering facts Recognizing tasks/ problems
↑	Classifying	Determining common qualities	Recognizing similarities and differences Grouping and sorting Comparing Making "either/or" distinctions
	Finding Relationships	Detecting regular operations	Relating parts and wholes Seeing patterns Analyzing Synthesizing Recognizing sequences and order Making deductions
↓	Transforming	Relating known to unknown	Making analogies Creating metaphors Making initial inductions
Complex	Drawing Conclusions	Assessing	Identifying cause and effect Making distinctions Inferring Evaluating

Moseley et al. (2005) reviewed over 30 taxonomies of thinking skills and constructed an integrated model, based on the review. The model consists of two dimensions: cognitive domain and metacognitive domain, and the cognitive domains identified in the model (which is of interest to this study) are shown in Table 8.

Table 8. Cognitive Skills (Moseley et al. 2005)

Cognitive Skills	
Information gathering	Experiencing Recognizing Comprehending messages and recorded information
Building understanding	Development of meaning (e.g. Elaborating, Representing, or Sharing ideas) Working with patterns and rules Concept formation Organizing ideas
Productive thinking	Reasoning Understanding causal relationships Systematic enquiry Problem-solving Creative thinking

Costa (2001) focused more on identifying behavioral objectives that can elicit different levels of thinking: Input, Processing, and Output (Table 9). At the first level of the model is Input, which represents cognitive processes related to information-gathering. When thinking at the input level, students are supposed to display cognitive behaviors, such as defining, completing, listing, reciting, matching, and counting. At the processing level, students make sense of the gathered information through analysis, classification, explanation, and comparison. Output level thinking requires students to go further beyond the concepts or principles that they have developed from the first two levels. Students are expected to use their knowledge and skills in a novel situation and to think creatively and hypothetically. The behavioral objectives related to this level of thinking include evaluating, predicting, hypothesizing, generalizing, and model building.

Table 9. Three Levels of Thinking (Costa 2001)

	Description	Example Behavior	
Input ↓	Gathering and Recalling Information	Complete Count Define Describe Identify List	Match Name Observe Recite Select Scan
Processing ↓	Making Sense Out of the Information Gathered	Compare Contrast Classify Sort Categorize Group Distinguish Explain (why)	Infer Sequence Analyze Synthesize Make analogies Reason Experiment
Output	Applying and Evaluating Actions in Novel Situations	Evaluate Generalize Imagine Judge Predict Speculate Extrapolate	If/Then Apply a principle Hypothesize Forecast Idealize Transfer Create

Frameworks of High Order Cognitive Processes

Not all cognitive processes are related to reasoning processes, which are one of the key components of spatial thinking. In the discipline of psychology, reasoning skills generally refer to cognitive processes, such as interpretation, analysis, comparison, inference, and evaluation (Quellmalz 1987). Quellmalz (1987) proposed a framework of Higher Order Thinking Strategies and Processes, in which four higher order cognitive processes were identified: Analyzing, Comparing, Inferring, and Evaluating (Table 10). These skills correspond to Costa's Processing and Output levels of thinking.

Table 10. High Order Cognitive Processes (Quellmalz 1987)

Skill	Examples
Analyze	Identify the components of a process, features of objects, or an argument
Compare	Compare the properties of objects, the causes and effects of events
Infer	Draw conclusions; Make predictions; Pose hypotheses
Evaluate	Evaluate the significance of findings or arguments

Gouge and Yates (2002) identified six reasoning patterns, which are thinking and reasoning skills particularly related to the arts (Table 11). Because the taxonomy was designed specifically for art education, the categories seem different from others presented above. However, there are many commonalities between the descriptions of reasoning skills presented in this taxonomy and those of higher order thinking skills presented in other taxonomies.

Table 11. Six Arts-specific Reasoning Patterns (Gouge and Yates 2002)

Reasoning Pattern	Description
Classification	The ability to group attributes or objects by one attribute and to shift to another attribute and regroup, according to new evidence, direct experience or need
Frames of reference	The ability to co-ordinate two systems, each involving a direct and inverse operation but with one of the systems in a relation of compensation or symmetry with respect to the other
Symbolic reasoning	The ability to link the use of symbols to increasingly sophisticated ways of communicating
Critical reflection	Invocation of independent ideas and consideration of all aspects of the context or situation under analysis
Intention, causality and experimentation	An interplay between thinking through actions before implementing them and systematic experimentation in order to reach desired outcomes

All the cognitive domains identified in the taxonomies of thinking skills reviewed in this study are summarized in Table 12.

Table 12. Taxonomies of Cognitive Processes

Taxonomies of Cognitive Processes							Taxonomies of Higher Order Cognitive Processes	
Bloom (1956)	Stahl & Murphy (1981)	Anderson &Krathwohl (2001)	Costa (2001)	Marzano (2001)	Presseisen (2001)	Moseley et al. (2005)	Quellmalz (1987)	Gouge & Yates (2002)
Knowledge	Preparation Reception	Remember	Input	Retrieval	Qualifying	Information gathering	Analyze	Classification
Comprehension	Transformation	Understand		Comprehension	Classifying		Compare	Frame reference
Application	Retention Transfersion (Applying)	Apply	Processing		Finding relations	Building understanding		Symbolic reasoning
Analysis	Incorporation	Analyze		Analysis	Transforming		Infer	Critical reflection
Synthesis	Organization	Evaluate	Output	Knowledge Utility	Draw conclusion	Productive thinking	Evaluate	Intention, causality & experimentation
Evaluation	Generation	Create						

Frameworks of Spatial Thinking

Bednarz (2004a) identified a list of aspects of spatial thinking most often developed through geography courses (Table 13). This is not a taxonomy in which classes or hierarchies among the component are conveyed, but considered helpful to construct a taxonomy of spatial thinking because it includes critical concepts (i.e., spatial distribution, pattern, hierarchy, and location) and cognitive processes (i.e., identify, recognize, imagine, and compare) associated with spatial thinking.

Table 13. Spatial Thinking Skills (Bednarz 2004a)

Spatial Thinking Skills
Abilities (skills) that recognize spatial distribution and spatial patterns
Identifying shapes
Recalling and representing layouts
Connecting locations
Associating and correlating spatially distributed phenomena
Comprehending and using spatial hierarchies
Regionalizing
Comprehending distance decay and nearest neighbor effects in distributions (buffering)
Wayfinding in real world frames of reference
Imagining maps from verbal descriptions
Sketch mapping
Comparing maps
Overlaying and dissolving maps (windowing)

Recently, an attempt to classify aspects of spatial thinking has been made by Gersmehl (2005; 2006). In the book, *Teaching Geography*, he proposed thirteen categories of spatial thinking, which are spatial thinking skills particularly relevant to K-12 geography. A taxonomy of spatial thinking was proposed one year later with a little change from the previous classification (Table 14). This taxonomy identifies critical spatial concepts discussed in geography and indicates some cognitive processes related to spatial thinking. However, one of the weaknesses of the taxonomy is that the significance of using a variety of spatial representations, one of the key components of spatial thinking, is unclear.

Table 14. Aspects of Spatial Thinking (Gersmehl 2005; 2006)

2005	2006
1. Expressing Location	0. Defining a Location
2. Describing Conditions at a Location	1. Describing Conditions
3. Tracing Connections with Other Locations	2. Tracing Spatial Connections
4. Comparing Locations	3. Making a Spatial Comparison
5. Determining the Zone of Influence around a Location	4. Inferring a Spatial Aura
6. Delimiting a Region of Similar Places	5. Delimiting a Region
7. Describing the Area between Places	6. Fitting a Place into a Spatial Hierarchy
8. Finding an Analog for a Given Place	7. Graphing a Spatial Transition
9. Identifying a Spatial Pattern	8. Identifying a Spatial Analog
10. Comparing Spatial Patterns	9. Discerning Spatial Patterns
11. Determining the Exceptions to a Rule	10. Assessing a Spatial Association
12. Analyzing Changes in Pattern Through Time	11. Designing and Using a Spatial Model
13. Devising Spatial Models	12. Mapping Spatial Exceptions

SUMMARY

Spatial thinking is a powerful way of problem solving in our daily lives, at the work place, as well as in science. Nevertheless, this important thinking skill has not been a part of formal education system. Learning geography can contribute to the development of spatial thinking skills if the emphases on the spatial perspectives of the National Geography Standards (1994) are fully implemented into school geography. Evidence is insufficient, however, that the expectations regarding spatial thinking presented in the Standards have been realized in the teacher practices, curricula support materials, and assessments, which mostly determine student experiences in the classroom.

Textbooks play critical roles in geography classrooms as an instructional tool, a curriculum, as well as the source of knowledge to be taught. Thus, geography textbooks must effectively address aspects of spatial thinking to help school geography support students' spatial thinking skills. However, few studies evaluated the degree to which aspects of spatial thinking appeared in various features, including questions, of the geography textbook. No valid criteria have been developed that can be used for such evaluation. Taxonomy can serve as a framework of the examination, but research has little focused on the development of a spatial thinking taxonomy.

The present study seeks to establish a valid taxonomy of spatial thinking. This study also aims to evaluate questions posed in secondary level geography textbooks in terms of three components of spatial thinking.

CHAPTER III

METHODOLOGY

This research was conducted in two phases. In the first phase, a body of literature was synthesized to construct a taxonomy of spatial thinking that can be used to assess spatiality of questions in textbooks as well as instructional materials and activities used in geography classes. The second phase of the study analyzed selected textbook questions against the taxonomy and determined the degree to which these questions address three key components of spatial thinking.

PHASE ONE: CREATION OF A SPATIAL THINKING TAXONOMY

The objective of Phase One was to address the first subordinate research question: How can aspects of spatial thinking be categorized? Findings of the previous research on spatial cognition, thinking skills, and taxonomies in education were synthesized to construct the three primary categories and the subcategories of each primary category of a spatial thinking taxonomy. The face validity and content validity of the taxonomy were examined by a panel of spatial thinking experts.

Three Primary Categories

To design a taxonomy is to construct categories of phenomena, and arrange and order the categories on the basis of a consistent set of principles (Krathwohl, Bloom, and Masia 1964). To construct a taxonomy of spatial thinking, therefore, is to identify categories of key aspects of spatial thinking and arrange them according to a consistent rule.

Three primary categories of the taxonomy were derived from the definition of spatial thinking as “a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning” (NRC 2006, 12). I adopted this definition because, first, I agreed with the view of spatial thinking as “broad sets of interconnected competencies” (NRC 2006, 26) for problem solving rather than an ability of spatial perception and mental rotation, which conceptualize spatiality in most psychology tests. It was also because this definition allows a systematic approach to teaching and learning to think spatially by breaking complex processes of spatial thinking into more explicit and concrete competencies - understanding concepts of space, using tools of representation, and reasoning. As a result, the three primary categories of the taxonomy were identified: Concept; Representation; and Cognitive Process.

Classification of the First Primary Category: Concept

Spatial thinking begins with structuring information using spatial concepts and with understanding spatially structured information (NRC 2006). A taxonomy of spatial thinking, which would serve as a set of criteria to assess the spatiality of concepts, therefore, should enable one to distinguish spatial concepts from non-spatial concepts foremost. At least two subcategories could be proposed: non-spatial concepts and spatial concepts.

In addition, a taxonomy of spatial thinking should be able to help classify a variety of spatial concepts in a reasonable way. Golledge's scheme (1995; 2002) of spatial concepts and classifications formed the basis for the categorization of the spatial concepts adopted in this study. Table 15 compares sets of spatial concepts proposed by Golledge both in 1995 and 2002. He first defined identity, location, magnitude, and time as spatial primitives and derived more complex spatial concepts by combining these primitives in various ways (e.g., region: multiple places). These concepts were arranged in increasing order of abstractness and complexity (Golledge 2002). Slight differences are found between the classifications of both studies, but twelve concepts were commonly identified: (place-specific) identity, location, magnitude, time, distance, (angle and) direction, boundary, (network, dominance, and) hierarchy, density (and distance decay), pattern, (clustering and) dispersion, and correlation (association).

For the present research, I adopted all of these common concepts, except 'time', as concepts of space to build a taxonomy. 'Time' was excluded for two reasons. First, time itself, as a concept, is not spatial in nature, admitting that many higher spatial concepts have to do with spatio-temporal relationships between features (e.g., diffusion). Second, using the concept of time as an independent spatial concept would cause overvaluing some textbook questions. For instance, a number of questions in geography textbooks ask: "When did something happen?" These questions have little to do with spatial thinking, but it would be coded as a question which addresses a spatial concept if 'time' were included in the spatial concepts category. Thus, to avoid such problems, 'time' was excluded.

Table 15. Spatial Concepts (Golledge 1995, 2002)

1995		2002	
Higher-order derived concepts	Network and Hierarchy Overlay Correlation	Higher-order concepts	Density & Distance Decay Spatial Association Pattern Clustering & Dispersion
Spatial distributions	Pattern and Shape Dispersion Density Boundary	First-order concepts	Spatial Hierarchy & Dominance Distribution and Arrangement Region Frame of Reference Orientation and Direction
First-order derived concepts	Connection and Linkage Sequence and Order Angle and Direction Distance	Primitives	Distance Boundary Time Magnitude Location Place-specific Identity
Primitives	Time Magnitude Location Identity		

Four concepts were added from another conceptualization of spatial concepts by Gersmehl (2005): connection, region, transition, and diffusion. These concepts were adopted because they are not only spatial but also considered important in school geography (Gersmehl 2005). Indeed, a pilot study conducted in 2006 confirmed these concepts appeared in high school geography textbooks. Additional spatial concepts were also identified from the pilot study: movement, shape, reference frame, arrangement, adjacency, enclosure, distribution, dominance, overlay, layer, buffer, gradient, profile, relief, scale, and map projection.

In total, 31 spatial concepts were categorized into three groups, each of which is assumed to represent a distinct level of abstractness and complexity. As Golledge (2002) argued, little attention has been paid in geography to defining primitives, which constitute the first class of the concept hierarchy and from which more complex geographic concepts can be derived. Nor does a consensus exist on how many classes are appropriate to categorize spatial concepts and which concepts should be categorized into which class. The present study classified spatial concepts into three groups: spatial primitives, simple-spatial, and complex-spatial, mostly following conceptualizations proposed by Golledge (1995; 2002). Spatial primitives are basic and fundamental characteristics of an existence in space, such as place-specific identity, location, and magnitude. Simple-spatial concepts are concepts that can be established by sets of spatial primitives (e.g., distance: interval between the locations), and complex-spatial concepts are those derived from sets of simple-spatial concepts (e.g., network: sets of connected locations) or from combinations of spatial primitives and simple-spatial concepts (e.g., hierarchy: from combining location and magnitude with connectivity). Concepts proposed by Gersmehl (2005; and 2006) and those identified in the pilot study were also synthesized. Finally, four subcategories constituted the first primary category of Concept (Table 16).

Table 16. Subcategories of the First Primary Category: Concept

Subcategory	Concepts
Non-spatial	e.g., GNP, population, terrorism
Spatial Primitives	Place-specific Identity, Location, Magnitude
Simple-Spatial	Distance, Direction, Connection and Linkage, Movement, Transition, Boundary, Region, Shape, Reference Frame, Arrangement, Adjacency, Enclosure
Complex-Spatial	Distribution, Pattern, Dispersion & Clustering, Density, Diffusion, Dominance, Hierarchy & Network, Spatial Association, Overlay, Layer, Gradient, Profile, Relief, Scale, Map projection, Buffer

Classification of the Second Primary Category: Representation

Using representations such as maps, diagrams, graphs, and charts is fundamental in spatial thinking (Bennett 2005; Geography Education Standards Project 1994; Greg and Leinhardt 1994; Tversky 2000, 2005; Uttal 2000). A taxonomy of spatial thinking, therefore, should acknowledge the use of representations as an effective tool to teach and learn spatial thinking so that one can evaluate spatiality of an instructional material or activity according to whether or not they encourage students to use tools of representations. Two subcategories were derived: non-use of representations and use of representations.

While concepts could be theoretically classified in more detail by complexity and abstractness, this was not the case with tools of representation. No framework was developed to classify representations in terms of complexity, nor did it seem possible or meaningful to do so. This is because the difficulty and complexity of an activity using representations depends on the learning context. That is, what kinds of concepts and cognitive processes are involved in the activity matters more than what types or characteristics of the representation are used. Such considerations were beyond the research questions of this study since the present study only concerned whether or not the textbook questions encourage students to use and create a variety of representations. Thus, only two subcategories were identified in the taxonomy: Non-use of representations and Use of representations.

Classification of the Third Primary Category: Cognitive Process

The core of reasoning is "going beyond the information given" (Bruner 1973). Reasoning requires higher levels of cognitive process, differentiated from just retrieving factual information (Costa 2001; Gouge and Yates 2002; Holyoak and Morrison 2005; Moseley et al. 2005; Quellmalz 1987). A taxonomy of spatial thinking, therefore, should be able to help distinguish cognitive processes relevant to higher order thinking from those irrelevant to it.

Table 17 summarizes nine taxonomies of thinking skills reviewed in Chapter II. Cognitive processes identified in seven taxonomies of general thinking skills and two taxonomies of higher order thinking skills were grouped into three different levels, based on the definition and descriptions of each cognitive domain as well as the hierarchies proposed in the taxonomies. Despite slight differences in terminologies, most of the taxonomies identified cognitive processes engaged to collect information, such as remembering and retrieving, as the lowest level of thinking. Commonly, cognitive processes, such as evaluating and creating, were considered the most complex and abstract level of thinking. Cognitive processes, such as analyzing, inferring, and applying, were considered higher levels of thinking but relatively simpler than cognitive processes such as evaluating, creating, and generalizing.

Costa's (2001) three different levels of thinking were used in this study as the subcategories of the third primary category because his classification is not only comprehensively covers the cognitive domains identified in other taxonomies of thinking skills, but it also is intuitive and easily applicable to the question analysis.

Table 17. Taxonomies of Thinking Skills and Higher-order Thinking Skills. Cognitive processes identified in the nine taxonomy of thinking skills were compared and grouped into three by level of complexity. Cognitive processes involved in gathering information were considered the lowest level (i.e., Knowledge, Remember, and Input), while those engaged to generating new knowledge or a product were considered the highest level (i.e., Evaluation, Create, Output)

Taxonomies of Cognitive Processes							Taxonomies of Higher Order Cognitive Processes	
Bloom (1956)	Stahl & Murphy (1981)	Anderson &Krathwohl (2001)	Costa (2001)	Marzano (2001)	Presseisen (2001)	Moseley et al. (2005)	Quellmalz (1987)	Gouge & Yates (2002)
Knowledge	Preparation Reception	Remember	Input	Retrieval	Qualifying	Information gathering	Analyze	Classification
Comprehension	Transformation	Understand						Frame reference
	Retention			Comprehension	Classifying		Compare	Symbolic reasoning
Application	Transfersion (Applying)	Apply	Processing		Finding relations	Building understanding		
Analysis	Incorporation	Analyze		Analysis	Transforming		Infer	Critical reflection
Synthesis	Organization	Evaluate	Output	Knowledge Utility	Draw conclusion	Productive thinking	Evaluate	Intention, causality & experimentation
Evaluation	Generation	Create						

The initial purpose of Costa's classification was to provide teachers with a guide to design classroom questions to facilitate students' thinking. In addition, previous research (Pizzini, Shepardson, and Abell 1992) assessing questions posed in middle school science textbooks used these categories thus confirming Costa's (2001) classification worked well in the question analysis, which is one of the objectives of this study.

A variety of cognitive processes were classified into three groups by the level of complexity (Table 18). "Input level" represents cognitive processes engaged to gather information from the senses including perception or to recall information from experiences or memories. Input level thinking processes include recalling, defining, identifying, and listing. Considering Bruner's definition of reasoning as "going beyond the information given," input level cognitive processes may not account for reasoning although they provide the basis to acquire the knowledge required for reasoning to occur. At the processing level, the learners analyze, classify, explain, or compare information acquired at the input level. This type of cognition is associated with reasoning since it requires making sense of collected information and, therefore, going beyond the information. Output level refers to generating new knowledge or products through evaluating, generalizing, and creating from the information obtained from the first two levels. These cognitive processes necessitate processes of reasoning and are considered the highest level in difficulty as well as in complexity. In sum, the three subcategories comprised of the last primary category of the taxonomy: Cognitive Process.

Table 18. Subcategories of the Third Primary Category: Cognitive Process (Costa 2001)

Subcategory	Characteristics of Activity	Relevant Cognitive Processes	
Input	Gathering and Recalling information	Naming Defining Listing Identifying Reciting Recalling	Observing Describing Selecting Completing Counting Matching
Processing	Making sense of gathered information	Synthesizing Analyzing Explaining Stating causality Classifying Categorizing Grouping Organizing	Comparing Contrasting Distinguishing Sequencing Inferring Experimenting Summarizing Making analogies
Output	Applying and Evaluating Actions in Novel Situation	Evaluating Judging Predicting Forecasting Planning Creating Designing Inventing	Hypothesizing Speculating Imagining Generalizing Model building Applying a principle Extrapolating

A Taxonomy of Spatial Thinking

A taxonomy of spatial thinking that can be used to assess textbook questions was constructed. The three primary categories and the subcategories of each primary category were visualized as a 4x3x2 cube in which each axis stands for one of the three primary categories of the taxonomy: Concept, Representation, and Cognitive process. These three primary categories were represented with three different color schemes (Concept: red; Representation; yellow; Cognitive process; blue), and the subcategories of each primary category were differentiated by varying degree of saturation along with each color scheme (Figure 1). Figure 2 illustrates the three-dimensional structure of the taxonomy where the three primary categories and the subcategories of each primary category were embedded.

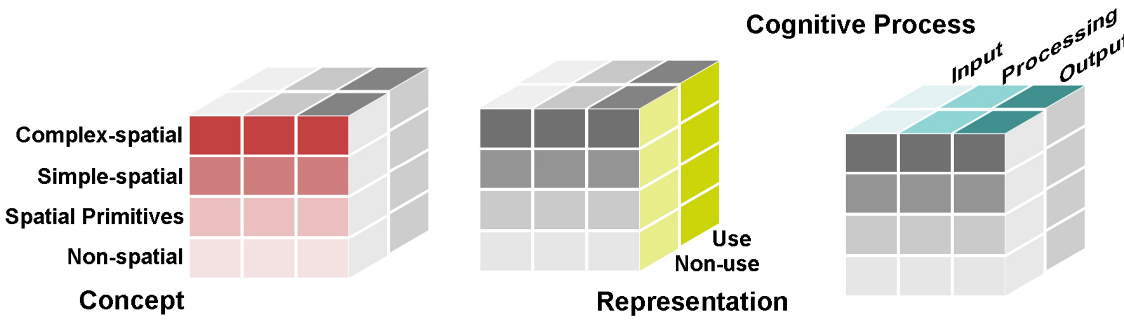


Figure 1. Three Components of Spatial Thinking Represented with Different Colors

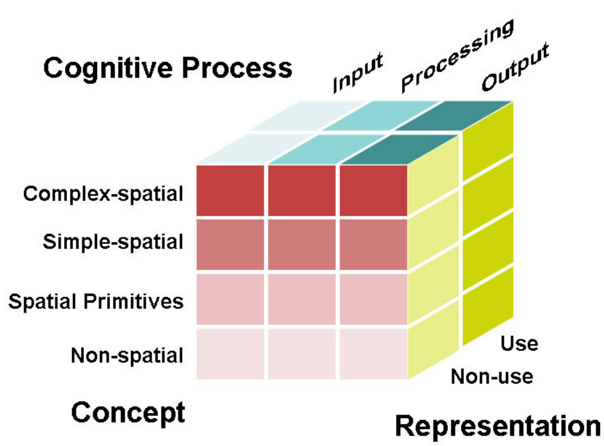


Figure 2. A Three-dimensional Taxonomy of Spatial Thinking

Validation of Taxonomy

The taxonomy was validated through a survey (Appendix A) of spatial thinking experts. Since there was no valid taxonomy of spatial thinking which can be used as a criterion for a more rigorous validity test (i.e., criterion-related validity, construct validity, and convergent and discriminant validity), this study only concerned face validity and content validity, which are necessary but relatively weak measures of validity. Face validity was defined as the extent to which the taxonomy of spatial thinking appears a measure of the three components of spatial thinking. Content validity referred to the degree to which the taxonomy represents aspects of spatial thinking identified in the definition. The survey consisted of ten questions: three questions regarding face validity; and seven questions regarding content validity. The taxonomy was rated on a 1 to 5 scale (1=strongly disagree, 5=strongly agree) for each question. Table 19 illustrates the relationship between each survey item and the validity examined.

Three professors and two graduate students in the Department of Geography, Texas A&M University, comprised the expert group. All of them were considered spatial thinking experts. First, they are professionals in geography, which is one of the disciplines concerning spatial perspectives. In addition, the three professors have been engaged in the project *"Advancing Geospatial Skills in Science and Social Science (AGSSS),"* which focused on the development of spatial thinking skills in secondary schools. Two of them are also experts in geography education. The two graduate students were selected because spatial thinking is the major part of their research interests. In addition, one of the students has been involved in studies of geography education as well. Thus, they were considered being familiar with the definition and aspects of spatial thinking that constituted the framework of this study.

Table 19. Relationship between Validity of the Taxonomy and Survey Items

Validity	Survey Question
Face Validity	1. Does the taxonomy seem to be measuring aspects of spatial thinking? 2. Does the taxonomy seem like a reasonable way to gain the information about whether geographic instructional materials incorporate three components of spatial thinking? 3. Does the taxonomy seem as though it will work reliably?
Content Validity	4. Does the taxonomy reflect the definition of spatial thinking? 5. Does the taxonomy reflect three key components of spatial thinking? 6. Are the concepts of space representative? 7. Are the cognitive processes representative? 8. Is the classification of concept appropriate? 9. Is the classification of representation appropriate? 10. Is the classification of cognitive process appropriate?

PHASE TWO: QUESTION EVALUATION

Phase One addressed Research Question 1: How can aspects of spatial thinking be categorized? Phase Two intended to address the second research question: What concepts, tools, and cognitive processes are required to answer the questions posed in geography textbooks? Four high school world geography textbooks commonly used in Texas were examined. Every question in the first two units of the selected textbooks was compared against the taxonomy. The degree of stimuli for spatial reasoning and for use of spatial representations was also measured.

Question Selection

Textbooks selected for Phase Two are the four textbooks adopted by the Texas Education Agency in 2003 for use in the high school course World Geography Studies. Student editions, not teacher editions, were examined in this study. The books have almost the same organization and structure, which adopts a systematic approach introducing geographic perspectives, methodologies, and general concepts in the first unit; followed by an examination of world regions for the remaining units (Table 20).

Table 20. Organization of the Selected Textbooks

		Textbook A	Textbook B	Textbook C	Textbook D
Systematic Approach	Unit 1	Looking at the World	The Geographer's World	The Basics of Geography	Physical and Human Geography
Regional Approach	Unit 2	The United States and Canada	The United States and Canada	The United States and Canada	The United States and Canada
	Unit 3	Latin America	Middle and South America	Latin America	Latin America
	Unit 4	Europe	Europe	Europe	Western Europe
	Unit 5	Russia and the Eurasian Republics	Russia and Northern Eurasia	Russia and the Republics	Central Europe and Northern Eurasia
	Unit 6	North Africa and Southwest Asia	Southwest Asia	Africa	Central and Southwest Asia
	Unit 7	Africa South of the Sahara	Africa	Southwest Asia	Africa
	Unit 8	South Asia	South Asia	South Asia	South Asia
	Unit 9	East Asia	East and Southeast Asia	East Asia	East Asia and the Pacific World
	Unit 10	Southeast Asia	The Pacific World	Southeast Asia, Oceania, and Antarctica	
	Unit 11	Australia, Oceania, and Antarctica			

All questions posed in Unit 1 and Unit 2 of each textbook were examined. Unit 1 and 2 were selected to compare the spatiality of questions presented in units that differently approach the subject matter of geography – a systematic approach and a regional. Unit two – The United States and Canada – was particularly selected out of the units about world regions, considering that the textbooks are used in the United States. A total of 3,010 questions were examined in this study (Table 21).

Table 21. Number of Questions Posed in Each Textbook, by Unit

	Textbook A		Textbook B		Textbook C		Textbook D		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Unit 1	388	63.1	659	70.3	427	53.4	365	55.5	1839	61.1
Unit 2	227	36.9	279	29.7	372	46.6	293	44.5	1171	38.9
Total	615	100.0	938	100.0	799	100.0	658	100.0	3010	100.0

Data Coding

Basic information about each question was coded, including textbook (i.e., A, B, C, or D), unit (i.e., 1 or 2), and chapter (i.e., 1, 2, and so forth). Page number and the question location were also coded. In this study, the question location referred to the physical positioning of the question in the textbook. For example, some questions were inserted within the textual content, and others were posed at the end of the chapter. However, different locations also indicated different purposes of the question. For instance, questions interspersed throughout the text are intended to monitor student comprehension of the textual content. On the other hand, questions presented in the page margin emphasize skill building. Questions provided at the end of sections and chapters were designed for comprehensive assessments that cover the overall knowledge and skills presented in the section or chapter. All the questions examined in this study were coded as to one of the five location categories: In text; Page margin; Supplemental section; End of section; and End of chapter. The number of questions by position is presented in Table 22.

Table 22. Number of Questions Posed in Each Textbook, by Question Location

	Textbook A		Textbook B		Textbook C		Textbook D		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
In Text	0	0.0	109	11.6	61	7.6	15	2.3	185	6.1
Page Margin	90	14.6	96	10.2	98	12.3	91	13.8	375	12.5
Supplemental Section	34	5.5	58	6.2	41	5.1	110	16.7	243	8.1
End of Section	261	42.4	352	37.5	280	35.0	238	36.2	1131	37.6
End of Chapter	230	37.5	323	34.4	319	39.9	204	31.0	1076	35.7
Total	615	100.0	938	100.0	799	100.0	658	100.0	3010	100.0

The spatiality of each question was examined according to the concepts, tools of representation, and cognitive processes that were required to answer the question. Then, every question was coded using the numbers assigned to each subcategory of the taxonomy developed in Phase One (Figure 3). An example of the coding is presented in Table 23. The question is a typical example of the questions which require knowledge about terms. Since the term “fishery” as in this case is non-spatial, it would be coded zero. Students were neither provided with a representation nor directed to use one from the textbook. So, this question should be coded zero in terms of the representation category. It might be coded Input because the cognitive processes required in this question are only recalling the definition and the meaning of the term and completing a given sentence.

Table 23. An Example of Question Coding

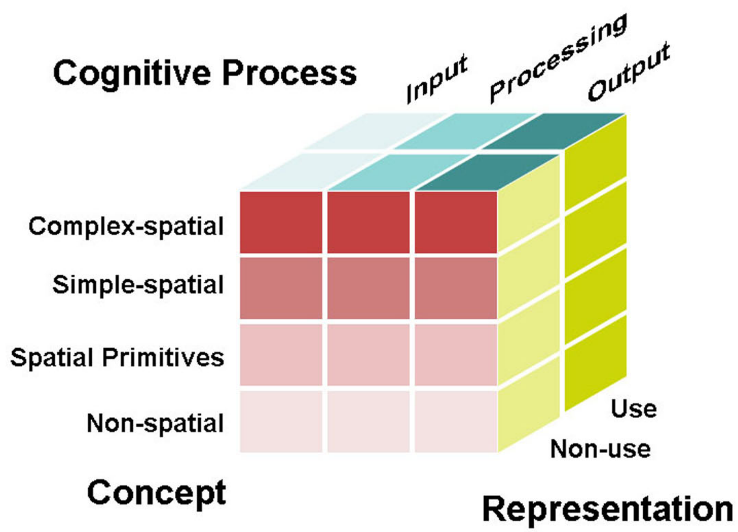
<table>
<tr><td colspan="3">Question: ______ supply great quantities of fish and other sea animals to North America.
Answer: Fishery</td></tr>
<tr><td>Concept</td><td>Representation</td><td>Cognitive Process</td></tr>
<tr><td>~~0~~ 1 2 3</td><td>~~0~~ 1</td><td>~~1~~ 2 3</td></tr>
<tr><td>Non-spatial</td><td>Non-use</td><td>Input</td></tr>
</table>

3: **Complex-Spatial**
Distribution
Pattern
Dispersion & Clustering
Density
Diffusion
Dominance
Hierarchy & Network
Spatial Association
Overlay
Layer
Gradient
Profile
Relief
Scale
Map Projection

2: **Simple-Spatial**
Distance
Direction
Connection & Linkage
Movement
Transition
Boundary
Region
Shape
Reference Frame
Arrangement
Adjacency
Enclosure

1: **Primitives**
Place-specific Identity
Location
Magnitude

0: **Non-spatial**



1: **Input**
Name
Define
List,
Identify
Recognize
Recite
Recall
Observe
Describe
Select
Complete
Count
Match

2: **Processing**
Explain
Analyze
State causality
Compare
Contrast
Distinguish
Classify
Categorize
Organize
Summarize
Synthesize
Infer
Make analogies
Exemplify
Experiment
Sequence

3: **Output**
Evaluate
Judge
Predict
Forcast
Hypothesize
Speculate
Plan
Create
Design
Invent
Imagine
Generalize
Build a model
Apply a principle

1: **Use**
Map
Diagram
Chart
Graph
Photo

0: **Non-use**

Figure 3. Question Coding Scheme. A Taxonomy of Spatial Thinking.

Data Analysis

Collected data were analyzed in two ways. First, an analysis of the questions in terms of each component of spatial thinking was conducted to answer the three subordinate questions of Research Question 2: a. What kinds of concepts are asked in the four high school world geography textbooks?; b. Do the questions require students to use or create a spatial representation?; and c. What kinds of cognitive processes are required to answer the questions? Descriptive statistic methods, such as frequencies, percentages, and cross tabulations were used to analyze and summarize the results.

Second, the degree to which the questions integrate the three components of spatial thinking was analyzed. This analysis was to answer the fourth subordinate questions of Research Question 2: d. Do the textbook questions integrate the three components of spatial thinking? Three-dimensional taxonomy constructed in Phase One was used as a framework to analyze and report the results.

The taxonomy was broken into 24 small pieces, of which each piece has a unique color combination that represents concept, representation, and cognitive process associated with (Figure 4). Numbers were assigned to each cell for convenient referring. Every question examined was categorized into one of the twenty four cells. For example, a question that required students to know the concept of "*location*"; to use a "*map*"; and to "*recall*" was categorized into Cell 10. If a question required students to understand the concept of "*overlay*"; to use multiple "*maps*"; and to "*evaluate*", it was categorized into Cell 24.

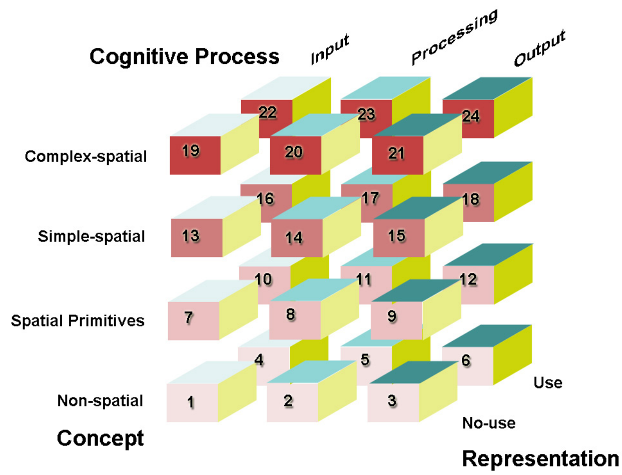


Figure 4. Twenty-four Cells of the Taxonomy (1). Each cell with different combination of colors represents its own special characteristic in terms of three components of spatial thinking. For example, Cell 1 stands for "*Non-spatial concept, No use of representation, and Input level cognitive process*". Numbers were assigned for convenience of subsequent analyses.

The analysis was done, based on the following premises. Cell 1 has nothing to do with spatial thinking, while Cell 24 definitely represents a complex level spatial thinking. Cells 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 19, 20, 21 as well as 1 represent questions that would not incorporate the three components. Questions that would be classified as Cells 10, 11, and 16 incorporate the three components but represent the simplest level spatial thinking, involved in relatively simple spatial concepts and low level cognitive processes. Cells 12, 17, and 22 represent higher level spatial thinking than cells 10, 11, and 16 but lower than Cells 18, 23, and 24. Cells 18, 23, and 24 represent spatial thinking with the highest complexity and abstractness, requiring knowledge about complex-spatial concepts as well as higher level of cognitive processes (Figure 5).

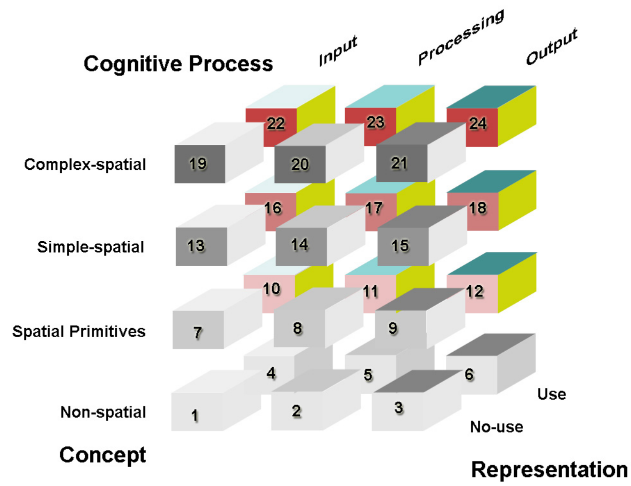


Figure 5. Twenty-four Cells of the Taxonomy (2). Gray-scaled cells represent questions where the three components of spatial thinking were not integrated, while colored cells stand for those where the three components are all incorporated. Among the colored cells, Cells 10, 11, and 16 represent the simplest level spatial thinking, whereas Cells 18, 23, and 24 stand for the most complex level.

Reliability Study

Coding is one of the research methods which rely heavily on the researcher's interpretation (Hodson 1999; Krippendorff 2004a; Weber 1985), making a reliability study a critical process in studies using this method. Inter-coder reliability was measured in this study using Krippendorff's α. While some popular reliability measures (e.g., percent agreement and Cohen's kappa) are only applicable to two coders, Krippendorff's α is applicable to any number of coders. In addition, it not only is applicable to any number of values, sample sizes, and scales (i.e., nominal, ordinal, interval, and ratio), but also controls agreement that might happen by chance (Krippendorff 2004b). Therefore, Krippendorff's α was considered one of the most general measure of inter-coder reliability and suitable for this study.

A panel of experts consisting of three professors and two graduate students at the Department of Geography at Texas A&M University participated in a one-hour training session for the question analysis. In the training session, the panel was given training materials (Appendix B) that included information about the purpose of the study, structure of the taxonomy, and five practice questions. Practice questions were extracted from a middle school geography textbook (Kracht 2003) to avoid coder bias in the analysis of the questions under study, which were sampled from high school textbooks.

After completing the training session, the panel coded a set of questions randomly sampled from the questions under study. It would be ideal for all of 3,010 questions being analyzed by all of the coders. Taking into consideration the number of questions, however, it must require substantial time commitment on the panel, so this method was not adopted for the present study. Instead, a sample of thirty questions (about 1 percent of the all cases) was selected using SPSS and used for the reliability study (Appendix C). Each member of the panel coded the questions according to the taxonomy given with the questions with no time-limit.

CHAPTER IV

RESULTS

This chapter examines the results and analyses of the study. As described in Chapter III, Phase One established a taxonomy of spatial thinking which can be used to assess the spatiality of textbook questions. The taxonomy was evaluated by a panel of experts in terms of its face validity and content validity. Results of the validity survey are reported.

Phase Two assessed 3,010 questions posed in the selected four high school world geography textbooks against the taxonomy. The spatiality of the concepts featured in the questions was analyzed. Then, the degree to which spatial representations and stimuli for reasoning were presented in the questions was also determined. Third, the degree to which the questions integrate the three components of spatial thinking was measured. Differences among the four textbooks, between the two units, and among five question locations were also examined. Finally, inter-coder reliability among five spatial thinking experts was measured on about one percent of the sample questions to ensure the reproducibility of the study results.

PHASE ONE: A TAXONOMY OF SPATIAL THINKING

The objective of Phase One was to answer the first research question:

1. How can aspects of spatial thinking be categorized?

   a. How can concepts of space be categorized?

   b. How can tools of representation be categorized?

   c. How can reasoning processes be categorized?

A Taxonomy of Spatial Thinking

In this study, taxonomy was defined as “a system of classification and the concepts underlying it” (Good 1973). A taxonomy of spatial thinking was constructed, based on the definition: “a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning” (NRC 2006). The taxonomy is a theory-based framework that classifies concepts and cognitive processes that constitute spatial thinking skills. The significance of using and creating representations in spatial thinking is also manifested in the taxonomy.

The taxonomy was visualized as a three-dimensional structure - a 4x3x2 cube, in which the three components constituted the three primary axes. The three primary categories were represented by three different color schemes: red for Concept; yellow for Representation; and blue for Cognitive Process. The subcategories of each primary category were represented by varying degrees of saturation along with each color scheme according to the complexity and abstractness. That is, the darker, the more complex.

The three-dimensional taxonomy was broken into twenty-four cells for analysis. The characteristic of each cell is unique in that it represents a unique combination of the subcategories of the three components of spatial thinking. For instance, Cell 1 represents a form of thinking related to non-spatial concepts, irrelevant to using a representation, and requiring the lowest level of cognitive process. Cell 24, on the other hand, represents a kind of thinking that requires understanding of complex-spatial concepts, using or creating a spatial representation, and the highest level of cognitive process. In sum, the taxonomy allows a detailed analysis of questions in terms of the three components of spatial thinking.

The taxonomy enables one to distinguish questions which integrate three components (Cells 10, 11, 12, 16, 17, 18, 22, 23, and 24) from those which do not (Cells 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 19, 20, and 21). Moreover, in the taxonomy, questions can be differentiated by level of spatial thinking involved. Cells 10, 11, and 16 of the taxonomy represent the simplest level of spatial thinking, involved in relatively simple spatial concepts and low level of cognitive processes. On the other hand, Cells 18, 23, and 24 stands for spatial thinking in the most complex level, requiring knowledge about complex-spatial concepts and higher level of cognitive processes.

Validity of Taxonomy

The taxonomy was validated through a survey (Appendix A) of five spatial thinking experts. The survey consisted of ten questions: three questions regarding face validity; and seven questions regarding content validity. The taxonomy was rated on a 1 to 5 scale (1=strongly disagree, 5=strongly agree) for each question. Each survey item and the average of expert judges follow.

Face Validity

Overall, the taxonomy was evaluated highly (4.3 out of 5) in face validity (Table 24). The experts mostly agreed that the taxonomy seems to be addressing aspects of spatial thinking and that the taxonomy looks like a reasonable way to obtain information about the degree to which a textbook question incorporates three components of spatial thinking (see Items 1 and 2). However, some experts showed concerns that the taxonomy might not work reliably (see Item 3).

Table 24. Face Validity of the Taxonomy

Question	Average
1. Does the taxonomy seem to be measuring aspects of spatial thinking?	4.6
2. Does the taxonomy seem like a reasonable way to gain the information about whether geographic instructional materials incorporate three components of spatial thinking?	4.6
3. Does the taxonomy seem as though it will work reliably?	3.8
Overall	4.3

Content Validity

The taxonomy received high content validity scores (4.6 out of 5) as well (Table 25). The taxonomy was judged that it reflects the definition and the three key components of spatial thinking well (see Items 4 and 5). In addition, the experts agreed the spatial concepts and cognitive processes covered in the taxonomy are fairly representative (see Items 6 and 7). The classifications of the taxonomy were considered reasonable.

Table 25. Content Validity of the Taxonomy

Question		Average
4. Does the taxonomy reflect the definition of spatial thinking?		4.8
5. Does the taxonomy reflect three key components of spatial thinking?		4.6
6. Are the concepts of space representative?		4.6
7. Are the cognitive processes representative?		4.6
8. Is the classification of spatial concepts appropriate?		4.4
9. Is the classification of tools of representation appropriate?		4.6
10. Is the classification of processes of reasoning appropriate?		4.4
	Overall	4.6

PHASE TWO: SPATIALITY OF TEXTBOOK QUESTIONS

Phase Two addressed the second research question:

2. What concepts, tools, and cognitive processes are required to answer the questions posed in the four high school world geography textbooks?
   a. What kinds of concepts are asked in the textbook questions?
   b. Do the questions require students to use or create a spatial representation?

c. What kinds of cognitive processes are required to answer the questions?

d. Do the textbook questions integrate the three components of spatial thinking?

Concepts of Space

What kinds of concepts were asked in the textbook questions? Table 26 shows that about 44 percent of 3,010 sample questions focused on non-spatial concepts. Questions asking spatial primitives, such as location, place-specific identity, and magnitude, were about 22 percent (679/3010); and questions asking simple-spatial concepts, including distance, direction, and region, were about 25 percent (748/3010). Only about 9 percent of the questions dealt with complex-spatial concepts, such as pattern, diffusion, and spatial association.

Table 26. Concepts Required, Overall

Concept	Frequency	Percent
Non-spatial	1318	43.79
Spatial primitive	679	22.46
Simple-spatial	748	24.85
Complex-spatial	265	8.80
Total	3010	100.00

Comparison by Textbook

The percentage of each category of concepts required in the questions was also analyzed by textbook. Commonly, non-spatial concepts were asked most, and complex-spatial concepts were least required in all textbooks examined. Textbook A contained more questions related to spatial primitives than simple-spatial concepts, while Textbooks B, C, and D asked simple-spatial concepts rather more than spatial primitives. Textbook C contained particularly more questions about simple-spatial concepts than the other books, almost the same proportion as non-spatial concepts (Figure 6 and Table 27).

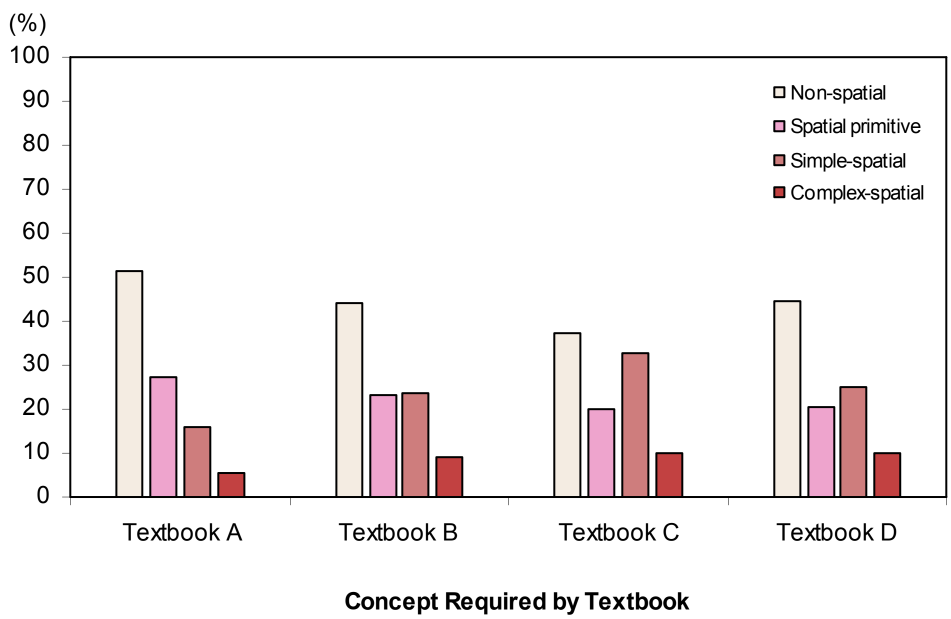


Figure 6. Concepts Required, by Textbook

Table 27. Concepts Required, by Textbook

	Textbook A		Textbook B		Textbook C		Textbook D	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Non-spatial	315	51.22	412	43.92	297	37.22	294	44.68
Spatial primitive	168	27.31	218	23.24	159	19.80	134	20.36
Simple-spatial	99	16.10	223	23.77	262	32.83	164	24.92
Complex-spatial	33	5.37	85	9.06	81	10.15	66	10.03
Total	615	100.00	938	100.00	799	100.00	658	100.00

Comparison by Unit

The concepts required in the questions were also analyzed by the unit where the questions were posed: Unit 1 or Unit 2. As indicated in the previous chapter, the first unit of each textbook takes a systematic approach to introduce geographic perspectives, methodologies, and concepts in general; and the second and following units take a regional approach presenting details on world regions. Figure 7 and Table 28 show the percent of each level of concepts by each unit. Over half of the questions presented in Unit 1 dealt with non-spatial concepts (52.09 percent, 958/1839), whereas only 8.16 percent of the questions were categorized as complex-spatial concepts. Questions in Unit 2 also asked many non-spatial concepts (30.74 percent, 360/1171) and relatively few complex-spatial concepts (9.82 percent, 115/1171). By far Unit 2 contained more questions associated with spatial concepts than Unit 1. Indeed, the difference in the percent between non-spatial concepts and spatial primitives were 34.91 for Unit 1, but only 0.26 for Unit 2.

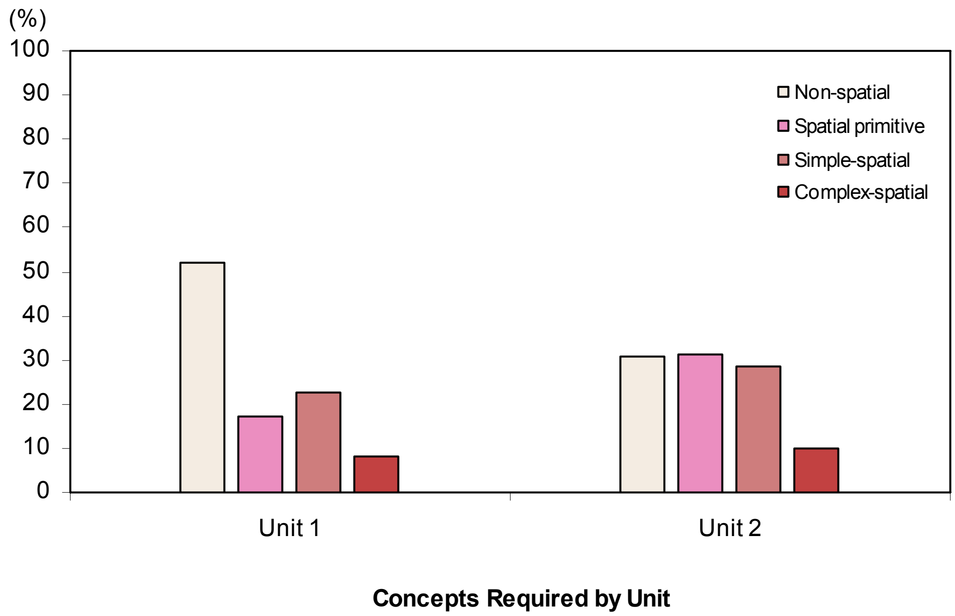


Figure 7. Concepts Required, by Unit

Table 28. Concepts Required, by Unit

	Unit 1		Unit 2	
	Frequency	Percent	Frequency	Percent
Non-spatial	958	52.09	360	30.74
Spatial primitive	316	17.18	363	31.00
Simple-spatial	415	22.57	333	28.44
Complex-spatial	150	8.16	115	9.82
Total	1839	100.00	1171	100.00

Figure 8 and Table 29 show the percentage of questions for each category of concepts by textbook as well as by unit. The four textbooks show similar patterns to the pattern observed in the aggregated result with two exceptions. One exception is found in Textbook A in terms of simple-spatial concepts. Unit 1 contained more questions asking simple-spatial concepts than Unit 2 in Textbook A, while Unit 2 included more simple-spatial concepts than Unit 1 in the other textbooks. The other exception is observed in Textbook C regarding the complex-spatial concept category. Unit 1 included slightly more complex-spatial concepts than Unit 2 in Textbook C, contrasting to the pattern observed in the other textbooks.

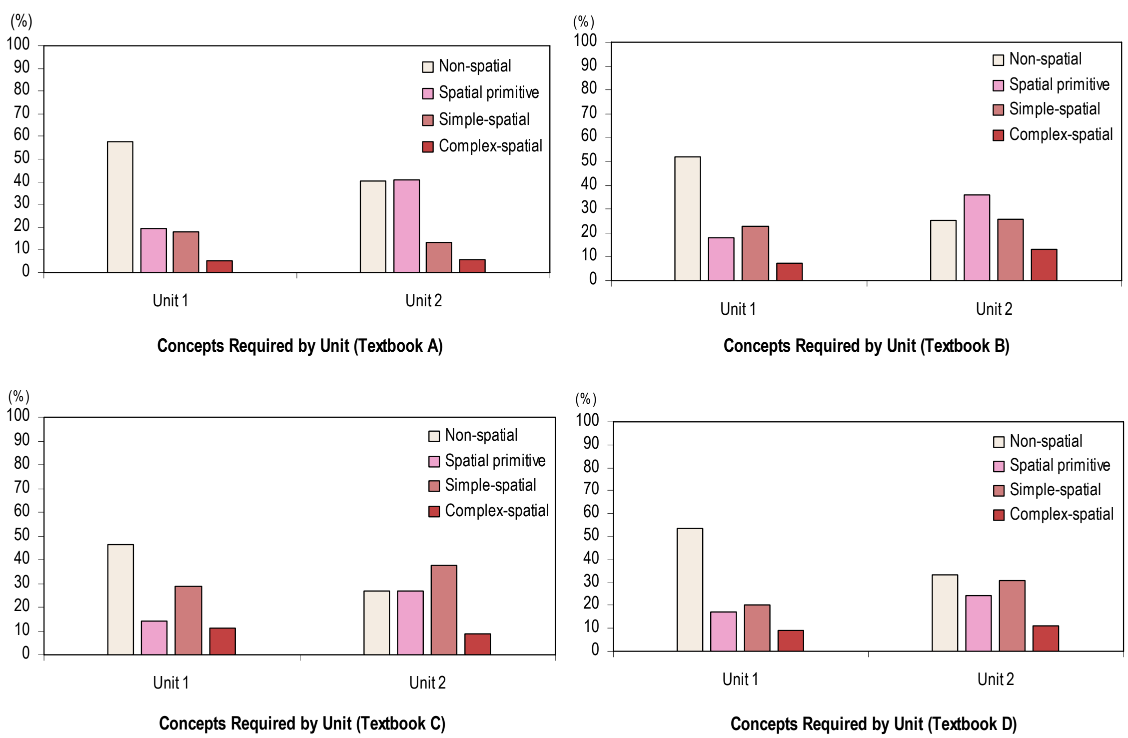


Figure 8. Concepts Required, by Unit and by Textbook

Table 29. Concepts Required, by Unit and by Textbook

		Unit 1		Unit 2	
		Frequency	Percent (within the Unit)	Frequency	Percent (within the Unit)
Non-spatial	Textbook A	224	57.73	91	40.09
	Textbook B	341	51.75	71	25.45
	Textbook C	197	46.14	100	26.88
	Textbook D	196	53.70	98	33.45
Spatial primitive	Textbook A	75	19.33	94	41.40
	Textbook B	118	17.91	100	35.84
	Textbook C	60	14.05	99	26.61
	Textbook D	63	17.26	71	24.23
Simple-spatial	Textbook A	69	17.78	30	13.22
	Textbook B	151	22.91	72	25.81
	Textbook C	122	28.57	140	37.63
	Textbook D	73	20.00	91	31.06
Complex-spatial	Textbook A	20	5.15	13	5.73
	Textbook B	49	7.44	36	12.90
	Textbook C	48	11.24	33	8.87
	Textbook D	33	9.04	33	11.26
Total	Textbook A	388	100.00	227	100.00
	Textbook B	659	100.00	279	100.00
	Textbook C	427	100.00	372	100.00
	Textbook D	365	100.00	293	100.00

Comparison by Question Location

The spatiality of concepts asked in the questions was analyzed by question location as well. In this study, categories of the question location referred to the physical positioning of the question: In text; Page margin; Supplemental section; End of section; and End of chapter. Different locations also indicated different purposes of the question. As described in Chapter III, questions in text are intended to monitor student comprehension of the textual content. On the other hand, questions presented in the page margin emphasize the acquisition of skills. Questions posed in the supplemental section ask knowledge and skills that students are expected to learn in that specific section. Questions provided at the end of sections and chapters were designed for comprehensive assessments that cover the overall knowledge and skills presented in the section or chapter.

The percentage of each level of concepts by question location is illustrated in Figure 9 and Table 30. About 34 percent of 185 questions posed in text were about non-spatial concepts, followed by simple-spatial concepts, spatial primitives, and complex-spatial concepts. In the page-margin questions, spatial primitives were most frequently asked (33.07 percent, 124/375), and simple-spatial concepts (28.53 percent, 107/375) were ranked secondly. Non-spatial concepts constituted only about 24 percent of the questions in page margins. Complex-spatial concepts appeared least frequently (14.17 percent, 53/375) in the questions posed in page margins. Questions posed in supplemental sections and at the end of chapters asked non-spatial concepts most and complex-spatial concepts least. Spatial primitives were asked slightly more than simple-spatial concepts. Over 50 percent of the questions located at the end of sections focused on non-spatial concepts (54.91 percent, 621/1131); followed by simple-spatial concepts (25.55 percent, 289/1131); spatial primitives (13.44 percent, 152/1131); and then complex-spatial concepts (6.10 percent, 69/1131).

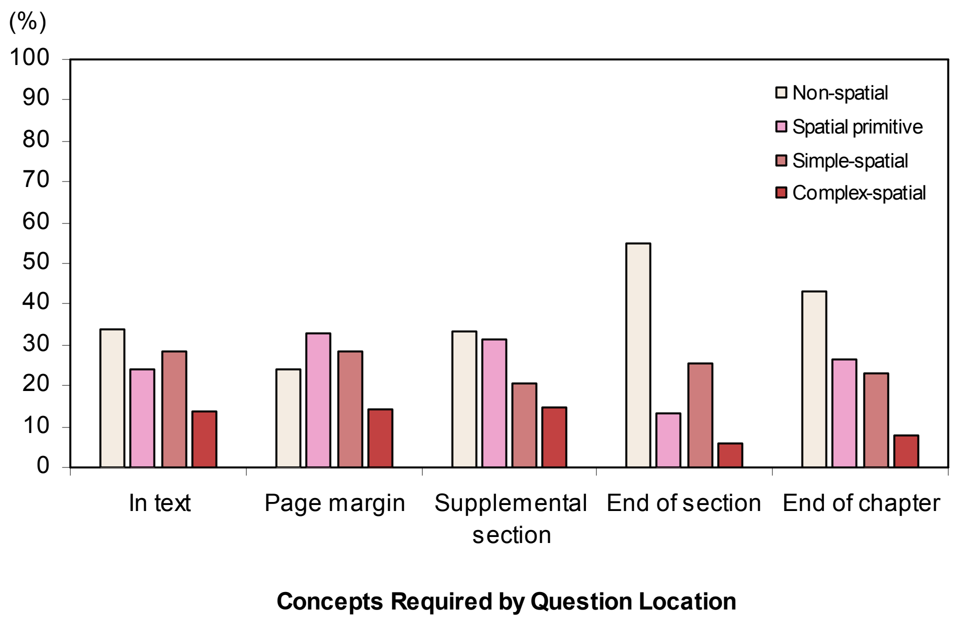


Figure 9. Concepts Required, by Question Location

Table 30. Concepts Required, by Question Location

	In text		Page margin		Supplemental section		End of section		End of chapter	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Non-spatial	63	34.05	91	24.27	81	33.33	621	54.91	462	42.94
Spatial primitive	44	23.78	124	33.07	76	31.28	152	13.44	283	26.30
Simple-spatial	53	28.65	107	28.53	50	20.58	289	25.55	249	23.14
Complex-spatial	25	13.51	53	14.13	36	14.81	69	6.10	82	7.62
Total	185	100.00	375	100.00	243	100.00	1131	100.00	1076	100.00

As shown in Figure 10 and Table 31, the four textbooks revealed similar patterns to the aggregated results in that questions posed at the end of a section and at the end of the chapter overwhelmingly asked non-spatial concepts. It was also quite similar to the overall result that questions posed in the page margin and in supplemental sections asked spatial concepts more than non-spatial concepts. One exception was found in Textbook A, in which non-spatial concepts were still most frequently asked even in questions located in page margins and in the supplemental section.

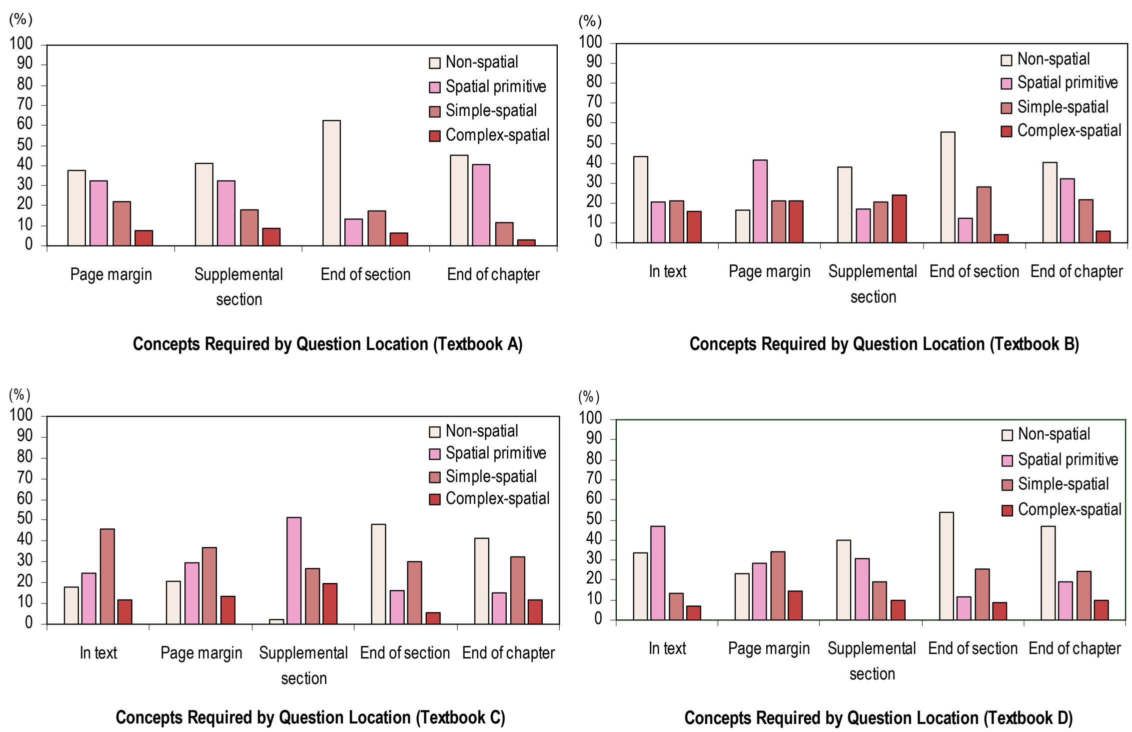


Figure 10. Concepts Required, by Question Location and by Textbook

Table 31. Concepts Required, by Question Location and by Textbook

		In text		Page margin		Supplemental section		End of section		End of chapter	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Non-spatial	Textbook A	-	-	34	37.78	14	41.18	163	62.45	104	45.22
	Textbook B	47	43.12	16	16.67	22	37.93	196	55.68	131	40.56
	Textbook C	11	18.03	20	20.41	1	2.44	134	47.86	131	41.07
	Textbook D	5	33.33	21	23.08	44	40.00	128	53.78	96	47.06
Spatial primitive	Textbook A	-	-	29	32.22	11	32.35	35	13.41	93	40.43
	Textbook B	22	20.18	40	41.67	10	17.24	43	12.22	103	31.89
	Textbook C	15	24.59	29	29.59	21	51.22	46	16.43	48	15.05
	Textbook D	7	46.67	26	28.57	34	30.91	28	11.76	39	19.12
Simple-spatial	Textbook A	-	-	20	22.22	6	17.65	46	17.62	27	11.74
	Textbook B	23	21.10	20	20.83	12	20.69	98	27.84	70	21.67
	Textbook C	28	45.90	36	36.73	11	26.83	84	30.00	103	32.29
	Textbook D	2	13.33	31	34.07	21	19.09	61	25.63	49	24.02
Complex-spatial	Textbook A	-	-	7	7.78	3	8.82	17	6.51	6	2.61
	Textbook B	17	15.60	20	20.83	14	24.14	15	4.26	19	5.88
	Textbook C	7	11.48	13	13.27	8	19.51	16	5.71	37	11.60
	Textbook D	1	6.67	13	14.29	11	10.00	21	8.82	20	9.80
Total	Textbook A	-	-	90	100.00	34	100.00	261	100.00	230	100.00
	Textbook B	109	100.00	96	100.00	58	100.00	352	100.00	323	100.00
	Textbook C	61	100.00	98	100.00	41	100.00	280	100.00	319	100.00
	Textbook D	15	100.00	91	100.00	110	100.00	238	100.00	204	100.00

Tools of Representation

Do the questions require students to use or create a spatial representation? As shown in Table 32, about 70 percent of 3,010 questions asked students neither to use nor to create representations to answer the questions.

Table 32. Representations Required, Overall

Representation	Frequency	Percent
Non-use	2085	69.27
Use	925	30.73
Total	3010	100.00

Comparison by Textbook

Overall, the four textbooks appeared similar in that there were more questions not requiring use of representations than those requiring it. However, a simple comparison of the percent indicates that questions in Textbook A required students to use representations most often (38.70 percent, 238/615), while questions in Textbook C required least (22.03 percent, 176/799) (Figure 11 and Table 33).

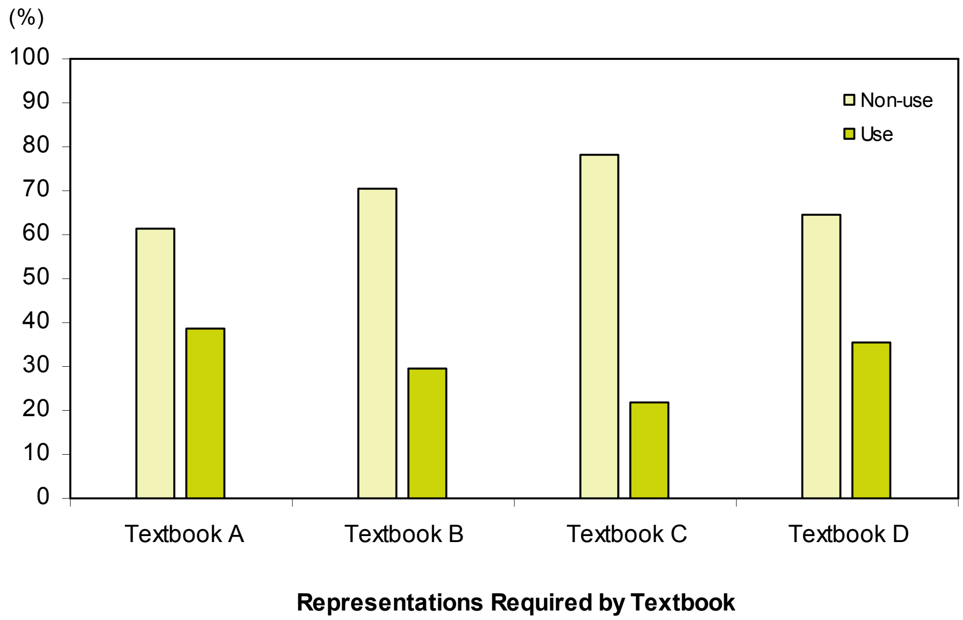


Figure 11. Representations Required, by Textbook

Table 33. Representations Required, by Textbook

	Textbook A		Textbook B		Textbook C		Textbook D	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Non-use	377	61.30	659	70.26	623	77.97	426	64.74
Use	238	38.70	279	29.74	176	22.03	232	35.26
Total	615	100.00	938	100.00	799	100.00	658	100.00

Comparison by Unit

The degree to which spatial representations were used in the questions by unit is illustrated in Figure 12 and Table 34. The majority of the questions in both units did not require students to use representations to answer the questions. However, Unit 2 included relatively more questions associated with using spatial representations (34.33 percent, 402/1171) than Unit 1 (28.44 percent, 523/1839).

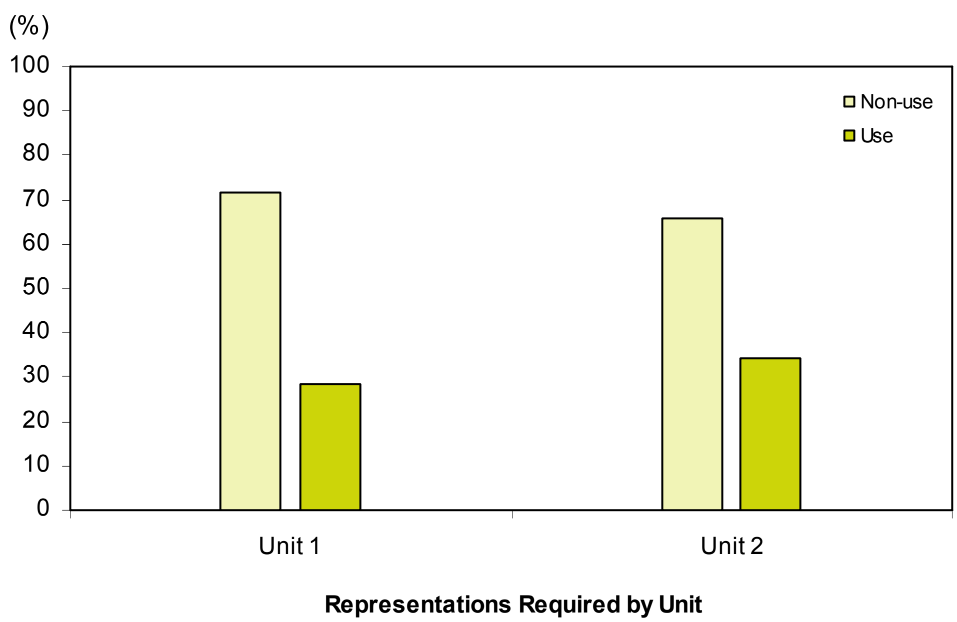


Figure 12. Representations Required, by Unit

Table 34. Representations Required, by Unit

	Unit 1		Unit 2	
	Frequency	Percent	Frequency	Percent
Non-use	1316	71.56	769	65.67
Use	523	28.44	402	34.33
Total	1839	100.00	1171	100.00

No difference was found among different textbooks from the pattern described in aggregated terms. In all textbooks, questions posed in Unit 2 asked using representations more often than those in Unit 1 (Figure 13 and Table 35).

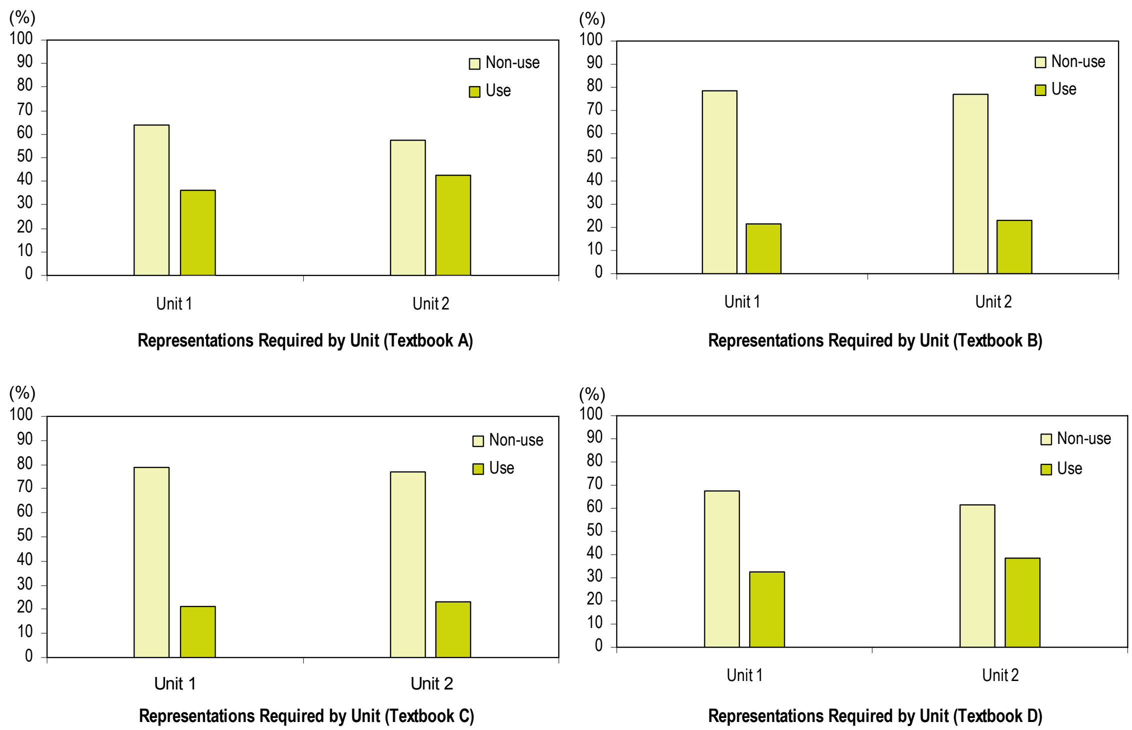


Figure 13. Representations Required, by Unit and by Textbook

Table 35. Representations Required, by Unit and by Textbook.

		Unit 1		Unit 2	
		Frequency	Percent	Frequency	Percent
Non-use	Textbook A	247	63.66	130	57.27
	Textbook B	487	73.90	172	61.65
	Textbook C	336	78.69	287	77.15
	Textbook D	246	67.40	180	61.43
Use	Textbook A	141	36.34	97	42.73
	Textbook B	172	26.10	107	38.35
	Textbook C	91	21.31	85	22.85
	Textbook D	119	32.60	113	38.57
Total	Textbook A	388	100.00	227	100.00
	Textbook B	659	100.00	279	100.00
	Textbook C	427	100.00	372	100.00
	Textbook D	365	100.00	293	100.00

Comparison by Question Location

The degree to which representations were used to answer questions by question location is presented in Figure 14 and Table 36. Almost all questions posed in the page margin required students to use spatial representations. In contrast, only about 8 percent of 1,131 questions presented at the end of sections called on students to use spatial representations. Using a representation was required in about 70 percent of 243 questions in the supplemental section, in about 25 percent of 1,076 questions located at the end of chapters, and in almost 19 percent of 185 in-text questions.

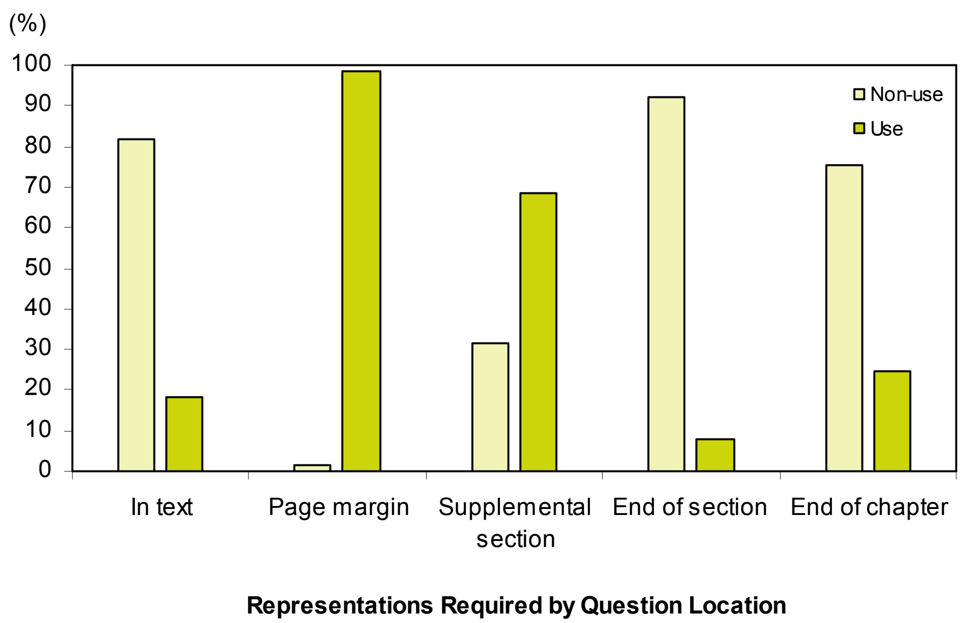


Figure 14. Representations Required, by Question Location

Table 36. Representations Required, by Question Location

	In text		Page margin		Supplemental section		End of section		End of chapter	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Non-use	151	81.62	6	1.60	77	31.69	1041	92.04	810	75.28
Use	34	18.38	369	98.40	166	68.31	90	7.96	266	24.72
Total	185	100.00	375	100.00	243	100.00	1131	100.00	1076	100.00

Four textbooks were similar in that questions located in text, at the end of a section, and at the end of the chapter rarely asked students to use or produce a representation. On the other hand, questions posed in the margin of each page and in supplemental sections guided students to use given representations or to generate a new one. Textbook D was an exception, showing 100 percent of in text questions requiring use of representations (Figure 15 and Table 37).

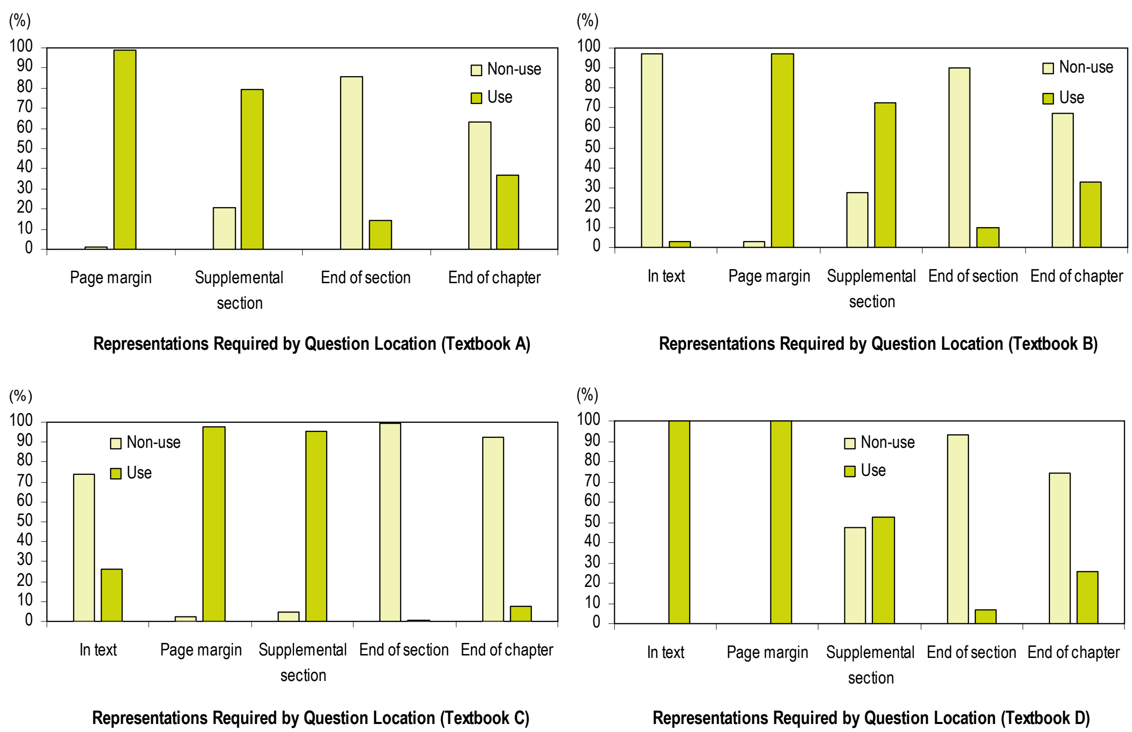


Figure 15. Representations Required, by Question Location and by Textbook

Table 37. Representations Required, by Question Location and by Textbook

		In text		Page margin		Supplemental section		End of section		End of chapter	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Non-use	Textbook A	-	-	1	1.11	7	20.59	224	85.82	145	63.04
	Textbook B	106	97.25	3	3.13	16	27.59	316	89.77	218	67.49
	Textbook C	45	73.77	2	2.04	2	4.88	279	99.64	295	92.48
	Textbook D	15	100.00	91	100.00	58	52.73	16	6.72	52	25.49
Use	Textbook A	-	-	89	98.89	27	79.41	37	14.18	85	36.96
	Textbook B	3	2.75	93	96.88	42	72.41	36	10.23	105	32.51
	Textbook C	16	26.23	96	97.96	39	95.12	1	0.36	24	7.52
	Textbook D	15	100.00	91	100.00	58	52.73	16	6.72	52	25.49
Total	Textbook A	-	-	90	100.00	34	100.00	261	100.00	230	100.00
	Textbook B	109	100.00	96	100.00	58	100.00	352	100.00	323	100.00
	Textbook C	61	100.00	98	100.00	41	100.00	280	100.00	319	100.00
	Textbook D	15	100.00	91	100.00	110	100.00	238	100.00	204	100.00

Processes of Reasoning

What kinds of cognitive processes are required to answer the questions? As explained in Chapter III, the reasoning process required to answer questions was assessed, based on the three levels of thinking proposed by Costa (2001): Input, Processing, and Output. Thinking in the Input level refers to the cognitive process involved in gathering information from the senses, experiences, and long- and short-term memories. Cognitive behaviors, such as defining, recognizing, identifying, matching, recalling, and listing, are included in this thinking level. At the Processing level, students are expected to make sense of information collected from the cognitive processes of the Input level through analysis, classification, explanation, and comparison. Output level's thinking called on generating new knowledge or products through generalization, creation, evaluation, prediction, and hypothesis from the information and knowledge acquired from the Input and Processing levels of thinking.

The results showed that over half questions out of 3,010 required the cognitive processes of Input level; slightly less than one third of the questions required Processing level thinking; and only 13 percent demanded Output level cognition (Table 38).

Table 38. Cognitive Processes Required, Overall

Cognitive Process	Frequency	Percent
Input	1748	58.07
Processing	868	28.84
Output	394	13.09
Total	3010	100.00

<u>*Comparison by Textbook*</u>

The percentage of questions by level of cognitive process and by textbook is presented in Figure 16 and Table 39. Textbook C contained Processing and Output level of thinking questions more than any other books. Textbook B asked the fewest Processing level questions (24.52 percent, 230/938), and Textbook A asked the fewest Output level questions (7.32 percent, 45/615), compared with other books.

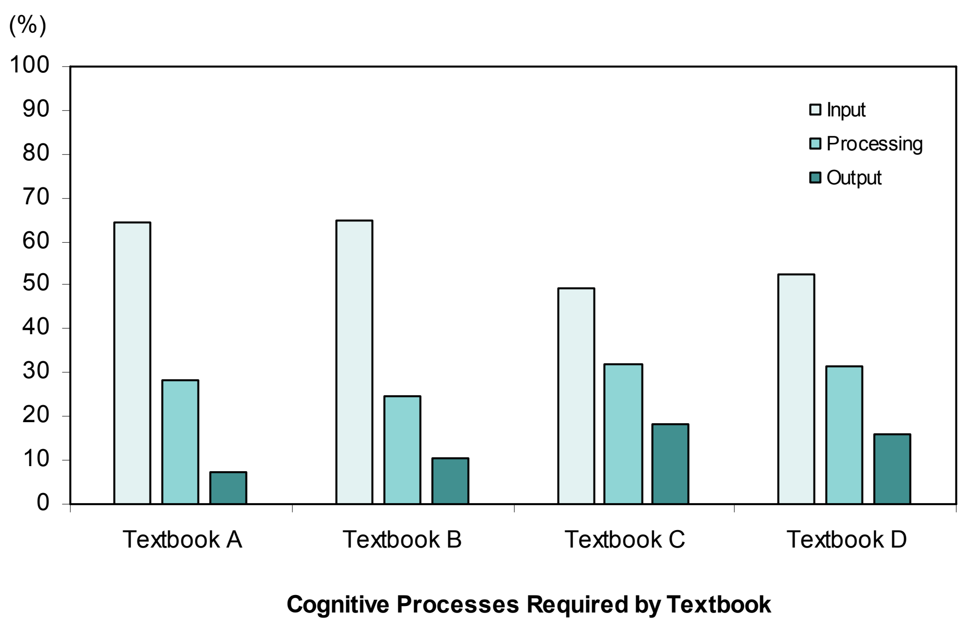


Figure 16. Cognitive Processes Required, by Textbook

Table 39. Cognitive Processes Required, by Textbook

	Textbook A		Textbook B		Textbook C		Textbook D	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Input	397	64.55	610	65.03	395	49.44	346	52.58
Processing	173	28.13	230	24.52	257	32.17	208	31.61
Output	45	7.32	98	10.45	147	18.40	104	15.81
Total	615	100.00	938	100.00	799	100.00	658	100.00

Comparison by Unit

The cognitive processes required in the questions were analyzed by unit as well. Questions posed in both Unit 1 and Unit 2 more frequently required Input level thinking than Processing or Output level thinking (Figure 17 and Table 40). However, Unit 2 included Processing and Output level questions more than Unit 1.

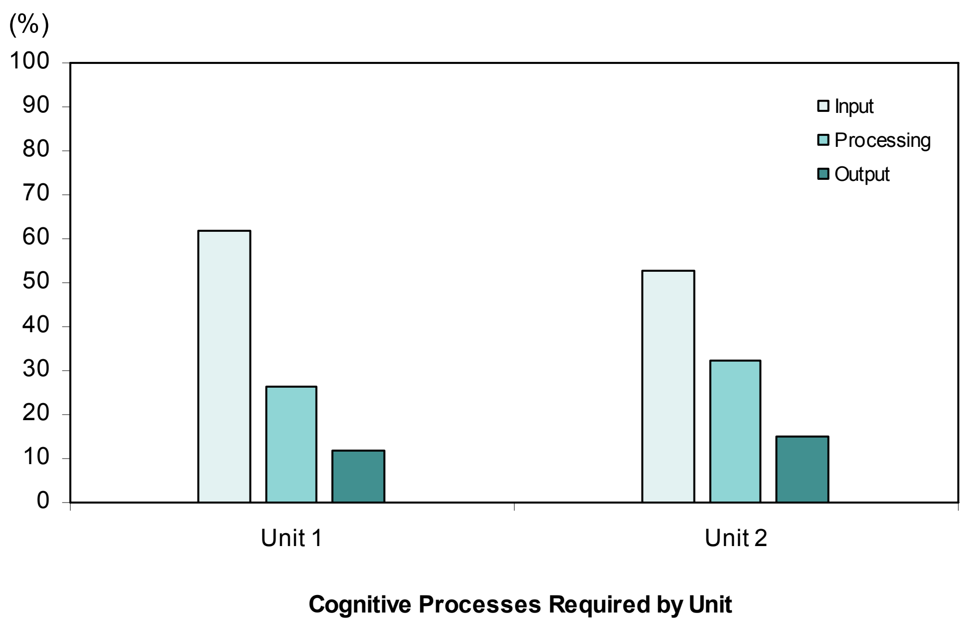


Figure 17. Cognitive Processes Required, by Unit

Table 40. Cognitive Processes Required, by Unit

	Unit 1		Unit 2	
	Frequency	Percent	Frequency	Percent
Input	1133	61.61	615	52.52
Processing	489	26.59	379	32.37
Output	217	11.80	177	15.12
Total	1839	100.00	1171	100.00

As shown in Figure 18 and Table 41, similar patterns were observed in all textbooks except Textbook A. In Textbook A, Unit 1 contained Processing and Output level questions more than Unit 1.

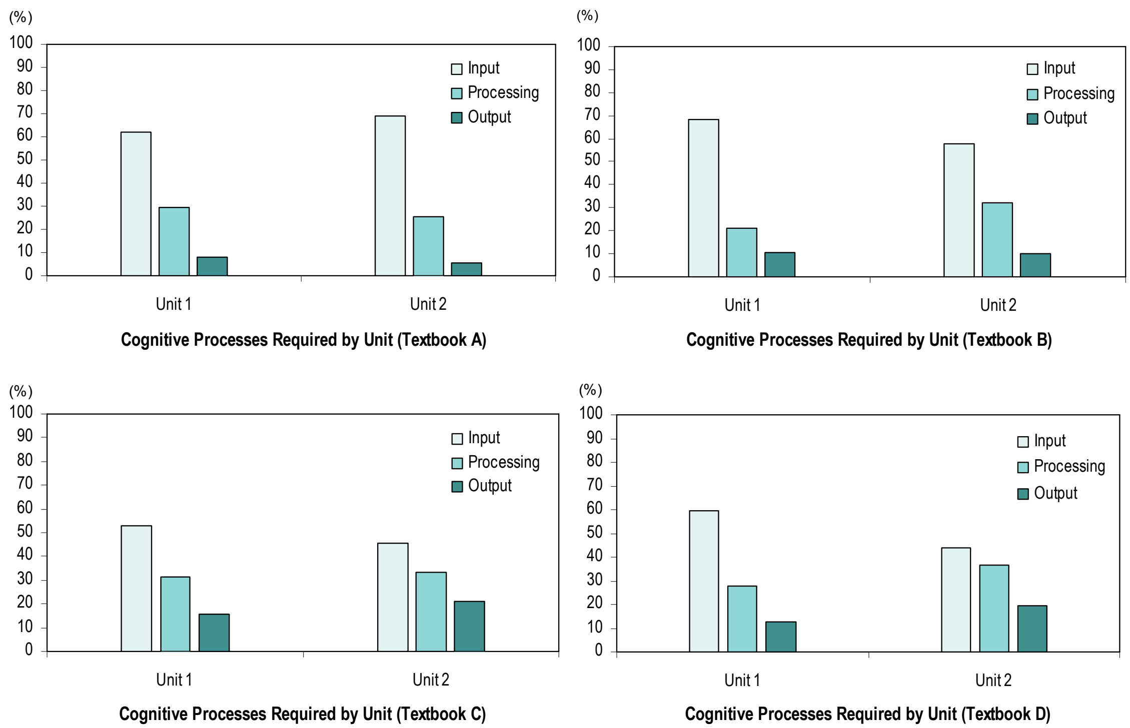


Figure 18. Cognitive Processes Required, by Unit and by Textbook

Table 41. Cognitive Processes Required, by Unit and by Textbook

		Unit 1		Unit 2	
		Frequency	Percent	Frequency	Percent
Input	Textbook A	241	62.11	156	69.03
	Textbook B	449	68.13	161	57.71
	Textbook C	226	52.93	169	45.43
	Textbook D	217	59.45	129	44.03
Processing	Textbook A	115	29.64	58	25.66
	Textbook B	140	21.24	90	32.26
	Textbook C	133	31.15	124	33.33
	Textbook D	101	27.67	107	36.52
Output	Textbook A	32	8.25	12	5.31
	Textbook B	70	10.62	28	10.04
	Textbook C	68	15.93	79	21.24
	Textbook D	47	12.88	57	19.45
Total	Textbook A	388	100.00	226	100.00
	Textbook B	659	100.00	279	100.00
	Textbook C	427	100.00	372	100.00
	Textbook D	365	100.00	293	100.00

<u>*Comparison by Question Location*</u>

Cognitive processes required in the questions were also analyzed by question location. Many questions posed in text required Input level thinking (47.03 percent, 87/185). Processing level questions followed next, and Output level questions appeared least. Questions located at the end of a section and end of the chapter showed similar patterns despite bigger difference between Input level and Processing level in the questions at the end of sections. Page-margin questions and the questions presented in supplemental sections frequently required Processing level thinking more than Input level. Questions requiring Output level thinking were featured least regardless of their locations (Figure 19 and Table 42).

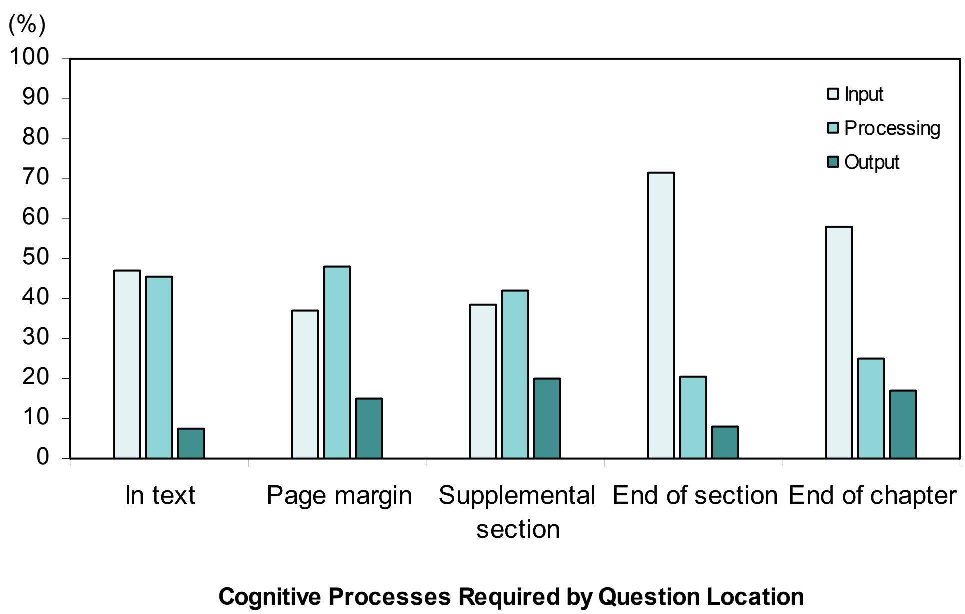


Figure 19. Cognitive Processes Required, by Question Location

Table 42. Cognitive Processes Required, by Question Location

	In text		Page margin		Supplemental section		End of section		End of chapter	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Input	87	47.03	139	37.07	93	38.27	806	71.26	623	57.90
Processing	84	45.41	180	48.00	102	41.98	233	20.60	269	25.00
Output	14	7.57	56	14.93	48	19.75	92	8.13	184	17.10
Total	185	100.00	375	100.00	243	100.00	1131	100.00	1076	100.00

All textbooks were the same in that questions at the end of sections required Input level thinking most. Questions in Textbook A even required Input level cognitive processes most regardless of their locations. A distinctive feature of Textbook B is that the questions requiring Output level thinking exceeded those requiring Input in the category Page margin. On the other hand in Textbook C, it was found that the three levels cognitive processes seemed balanced in the category End of chapter (Figure 20 and Table 43).

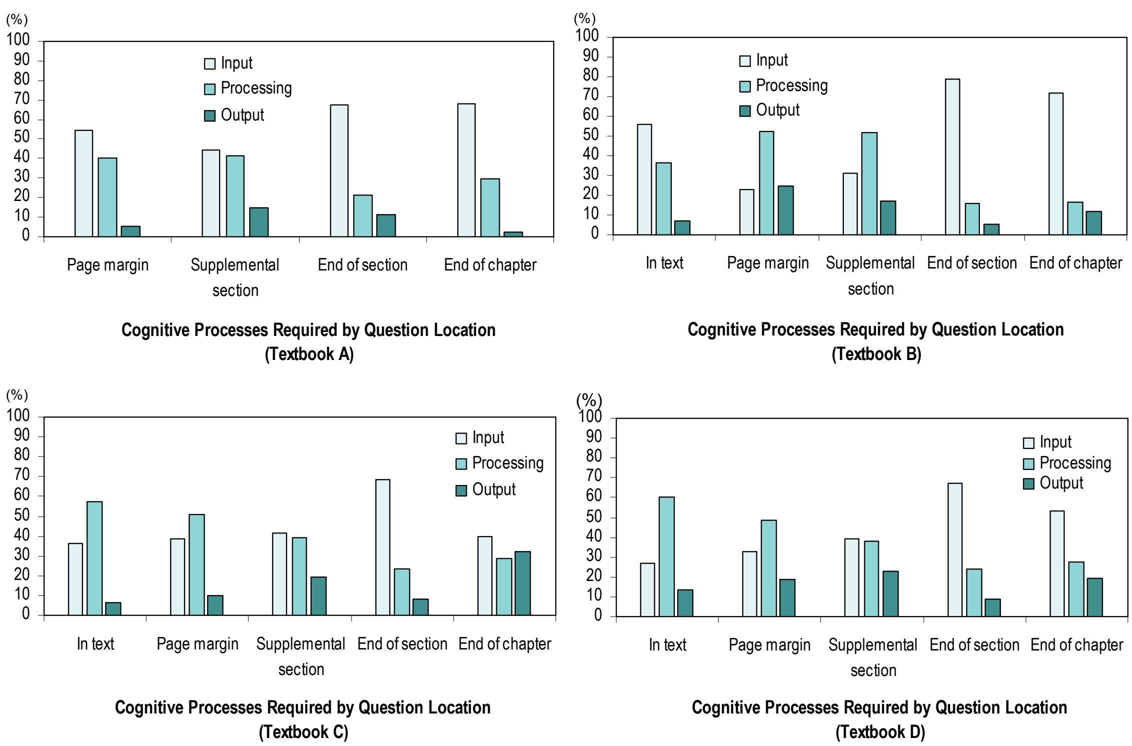


Figure 20. Cognitive Processes Required, by Question Location and by Textbook

Table 43. Cognitive Processes Required, by Question Location and by Textbook

		In text		Page margin		Supplemental section		End of section		End of chapter	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Input	Textbook A	-	-	49	54.44	15	44.12	176	67.43	157	68.26
	Textbook B	61	55.96	22	22.92	18	31.03	278	78.98	231	71.52
	Textbook C	22	36.07	38	38.78	17	41.46	192	68.57	126	39.50
	Textbook D	4	26.67	30	32.97	43	39.09	160	67.23	109	53.43
Processing	Textbook A	-	-	36	40.00	14	41.18	55	21.07	68	29.57
	Textbook B	40	36.70	50	52.08	30	51.72	56	15.91	54	16.72
	Textbook C	35	57.38	50	51.02	16	39.02	65	23.21	91	28.53
	Textbook D	9	60.00	44	48.35	42	38.18	57	23.95	56	27.45
Output	Textbook A	-	-	5	5.56	5	14.71	30	11.49	5	2.17
	Textbook B	8	7.34	24	25.00	10	17.24	18	5.11	38	11.76
	Textbook C	4	6.56	10	10.20	8	19.51	23	8.21	102	31.97
	Textbook D	2	13.33	17	18.68	25	22.73	21	8.82	39	19.12
Total	Textbook A	-	-	90	100.00	34	100.00	261	100.00	230	100.00
	Textbook B	109	100.00	96	100.00	58	100.00	352	100.00	323	100.00
	Textbook C	61	100.00	98	100.00	41	100.00	280	100.00	319	100.00
	Textbook D	15	100.00	91	100.00	110	100.00	238	100.00	204	100.00

Integration of the Three Components

Do the textbook questions integrate the three components of spatial thinking? As described in Chapter III, the degree to which the questions integrate three components of spatial thinking was analyzed using the taxonomy developed in Phase One. Questions were characterized and differentiated in relation to the twenty four cells that constitute the taxonomy. Questions categorized into Cells 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 19, 20, and 21 represent those which did not integrate the three components, while questions classified into Cells 10, 11, 12, 16, 17, 18, 22, 23, and 24 represent those incorporating all the three components. Cells representing integration of three components were differentiated by the complexity of concepts and cognitive processes involved: Cells 10, 11, and 16; Cells 12, 17, and 22; and Cells 18, 23, and 24. The three groups of cells represent different levels of spatial thinking.

Overall, about 76 percent of 3,010 questions lacked integration of the three components. Of the other 24 percent questions (728/3010), in which all three components were incorporated, 62 percent (453/728) required the simplest level spatial thinking, focusing on spatial primitives or Input level thinking. Only about 18 percent of the questions (129/728) required complex level spatial thinking involved in complex-spatial concepts or Output level cognitive processes (Figure 21).

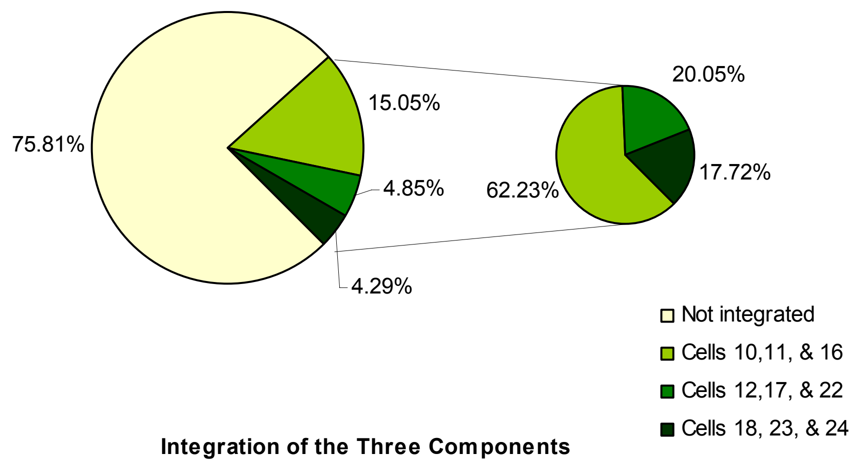


Figure 21. Integration of the Three Components, Overall

Comparison by Textbook

The four textbooks were similar in that over 70 percent of their questions rarely integrated the three components, despite some variation in the degree (Figure 22). In all books, over 50 percent of the other 30 percent questions were related to either spatial primitive or input level thinking (Cells 10, 11, and 16). The percentage of the questions represented by the category Cells 12, 17, and 22 followed next in Textbooks A, C, and D. In contrast, in Textbook B, there were more questions classified as Cells 18, 23, and 24 than those categorized as Cells 12, 17, and 22.

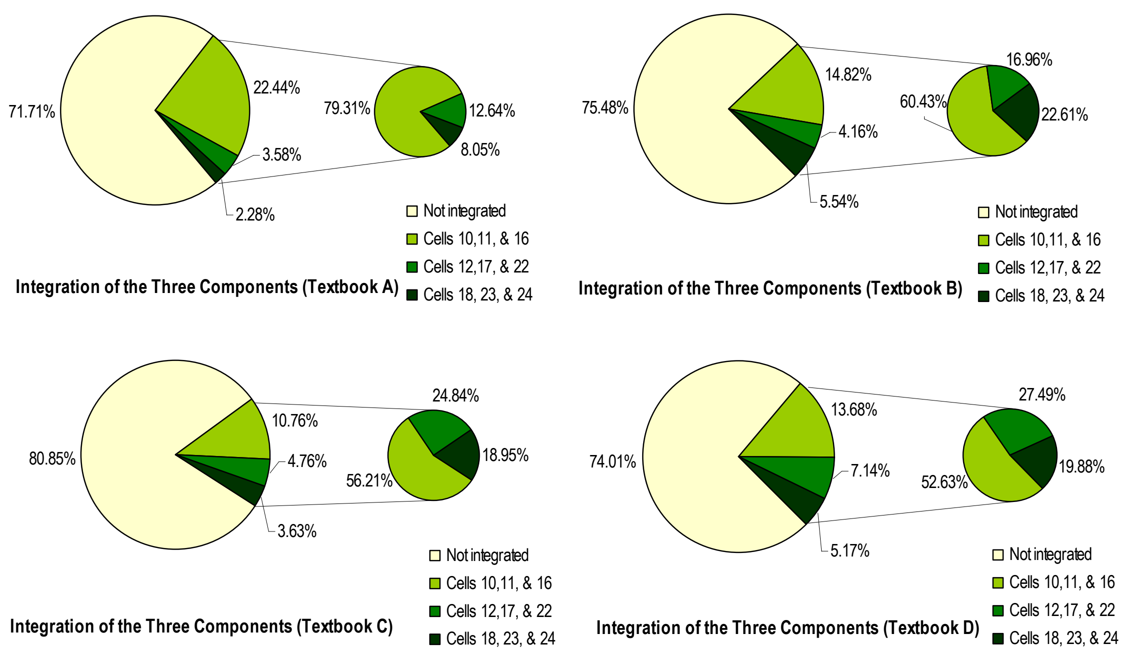


Figure 22. Integration of the Three Components, by Textbook

Comparison by Unit

Figure 23 shows that Unit 2 included questions integrating the three components more than Unit 1. Unit 2 also contained more questions for the category Cells 18, 23, and 24 than for the category Cells 12, 17, and 22. However, there was little difference between the two units in that questions which required the simplest level spatial thinking (Cells 10, 11, and 16) were the majority of the questions integrating the three components.

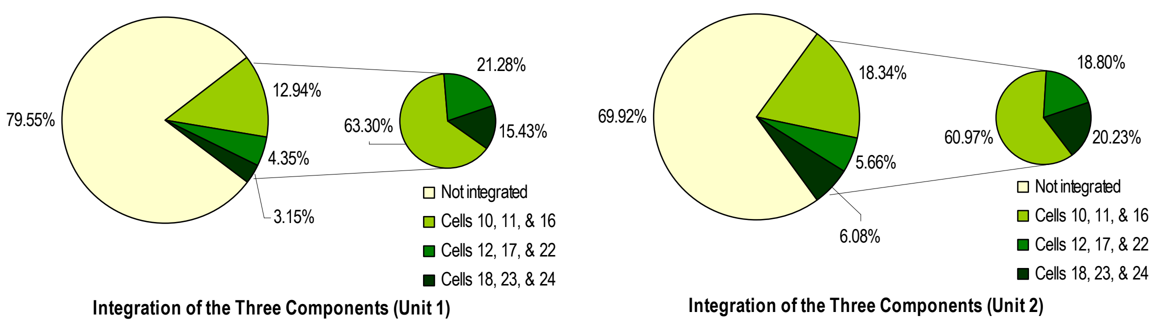


Figure 23. Integration of the Three Components, by Unit

Comparison by Question Location

The degree of integration was quite different by question location: In text; Page margin; Supplemental section; End of section; and End of chapter. As shown in Figure 24, the majority of the questions inserted in text (84.89 percent, 157/185), posed at the end of sections (93.90 percent, 1062/1131), and posed at the end of chapters (79.46

percent, 855/1076) lacked integration of the three components. There were more questions incorporating the three components in the questions located in the page margin (74.93 percent, 281/375) and in the supplemental section (52.64 percent 128/243). Among these questions, however, over half of them were categorized as Cells 10, 11, and 16, which represents the simplest level spatial thinking (Figure 24).

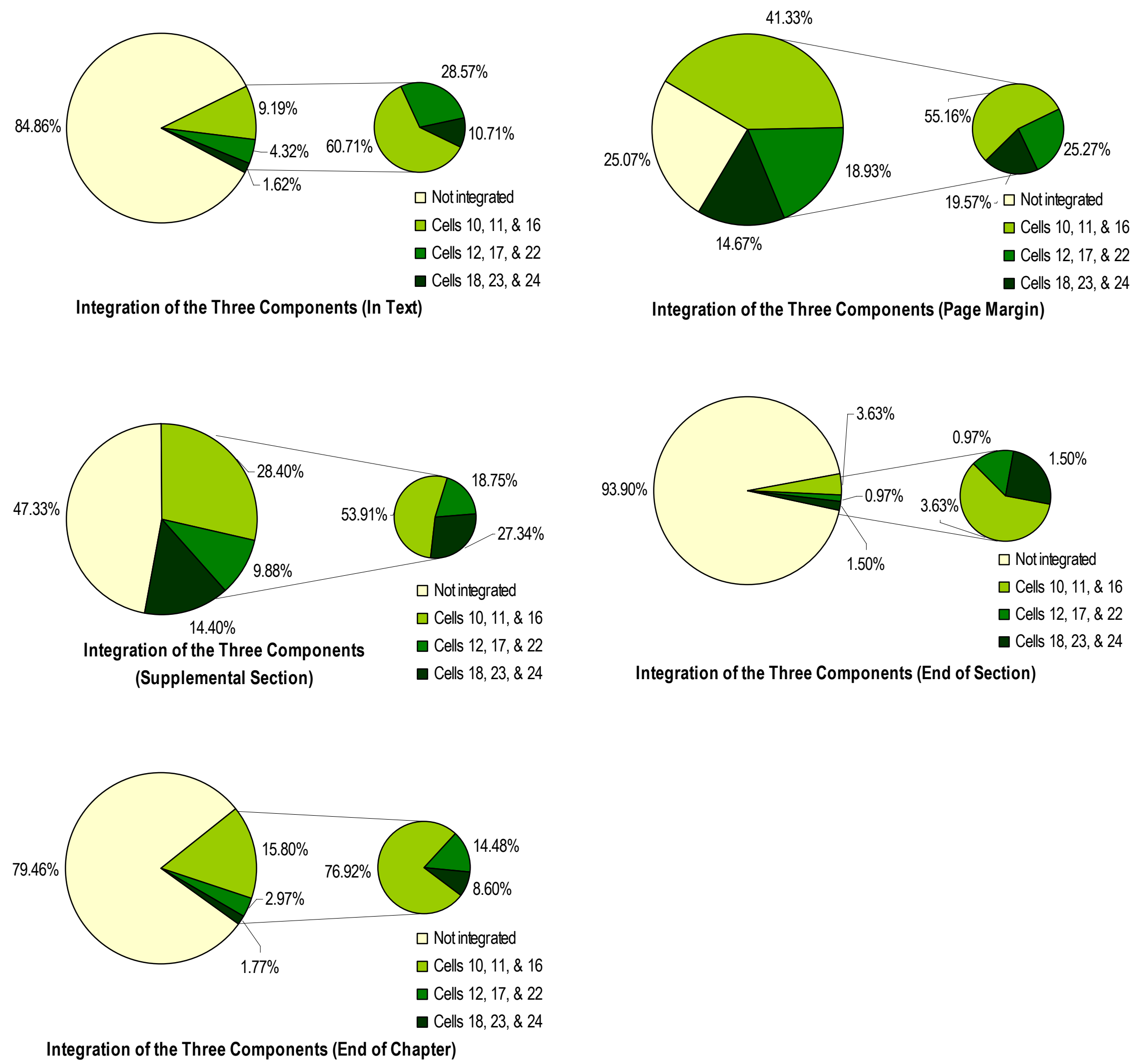


Figure 24. Integration of the Three Components, by Question Location

Inter-coder Reliability: Reproducibility of the Results

Five spatial thinking experts participated in the reliability study. Inter-coder reliability on thirty sample questions (about 1 percent of the whole sample, Appendix C) was assessed for each primary category of the taxonomy: Concept; Representation; and Cognitive Process. Krippendorff's α was used as the measure of reliability.

The values of α were .98 for the category Representation and .68 for the category Cognitive Process (Table 44). These values are above the cutoff (the smallest acceptable α is .67). Considering that Krippendorff's α is one of the most conservative (stringent) indices of reliability (Lombard, Snyder-Duch, and Bracken 2002), the values of α for the categories Representation and Cognitive Process indicate high reproducibility of the study results. The α value for the category Concept (.59) was a little below the acceptance level. Disagreements in the coding were resulted from the fact that the experts often undervalued the concepts than the researcher. It means the percent of non-spatial or simpler spatial concepts would be larger than the results reported in this study if the experts coded the whole sample. Low α value for the category Concept, therefore, will little harm the reliability of the general results of the study, which showed far more questions asked non-spatial or relatively simple-spatial concepts than complex-spatial concepts.

Table 44. Inter-coder Reliability of the Sample Question Coding

	Concept	Representation	Cognitive Process
Krippendorff's α	0.59	0.98	0.68

CHAPTER V

DISCUSSION AND CONCLUSIONS

This study constructed a taxonomy of spatial thinking which can be used to evaluate the spatiality of geography textbook questions. Three key components of spatial thinking identified in the definition of spatial thinking constituted the three primary categories of the taxonomy: Concept, Representation, and Cognitive Process. Using the taxonomy, a total of 3,010 questions posed in the first two units of the four high school world geography textbooks were assessed. The spatiality of concepts asked in the questions and the degree to which spatial representations and stimuli for reasoning were presented were measured. The degree to which the three components of spatial thinking were integrated in the questions was examined. The differences among the four textbooks, between the two units, and among the five different question locations were analyzed as well.

This chapter provides interpretation and implications of the study. The discussion is organized in the same order as the research questions:

1. How can aspects of spatial thinking be categorized?
    a. How can concepts of space be categorized?
    b. How can tools of representation be categorized?
    c. How can reasoning processes be categorized?
2. What concepts, tools, and cognitive processes are required to answer the questions posed in high school level geography textbooks?

a. What kinds of concepts are asked in the textbook questions?

b. Do the questions require students to use or create a spatial representation?

c. What kinds of cognitive processes are required to answer the questions?

d. Do the questions integrate the three components of spatial thinking?

A summary and conclusions follow. Suggestions for future research are also presented.

RESEARCH QUESTION 1: A TAXONOMY OF SPATIAL THINKING

Research Question 1a

How can concepts of space be categorized? There have been attempts to define and classify primitives and other spatial concepts (e.g., Golledge 1995, 2002; Gersmehl 2005), but there have been few studies to synthesize these conceptualizations and classifications. Little attempt was made to compare the relevance of the concepts taught in school geography to the spatial concepts identified in the literature. The present study not only integrated spatial concepts identified in previous research but also recognized some other spatial concepts that were not specified in the research but appeared in high school geography textbooks, such as movement and map projection. The concepts of space covered in this study, therefore, are more inclusive than those identified in previous studies. The result of a survey of spatial thinking experts confirmed that those concepts were highly representative as well as comprehensive.

It does not mean, however, that the concept list proposed in this study always is generalizable to other disciplines. Rather, specific lists of spatial concepts could be made in domain specific contexts. Spatial thinking skills are considered important not only in geography but also in other disciplines, such as mathematics, physics, astronomy, and geology. Each discipline might have sets of distinctive vocabulary related to spatial thinking. For example, concepts such as, minima, maxima, hyperbola, circle, and ellipse are spatial concepts featured in mathematics and geometry more than in geography and geology. The spatial concepts listed in the taxonomy, constructed in this study, are highly geographical although some concepts, such as magnitude, shape, and hierarchy, are common spatial concepts used in other disciplines.

As Golledge (2002) pointed out, little attention has been paid in geography to defining primitives, which constitute the first class of the concept hierarchy and from which more complex geographic concepts can be derived. Nor does a consensus exist on how many classes are appropriate to categorize spatial concepts, and which concepts should be categorized into which class. The present study proposed three classes of spatial concepts: primitives, simple-spatial, and complex-spatial. Spatial primitives are basic and fundamental characteristics of an existence in space, such as place-specific identity, location, and magnitude. Simple-spatial concepts are concepts that can be established by sets of spatial primitives (e.g., distance: interval between the locations), and complex-spatial concepts are those derived from sets of simple-spatial concepts (e.g., network: sets of connected locations) or from combinations of spatial primitives and simple-spatial concepts (e.g., hierarchy: from combining location and magnitude with connectivity). The classification proposed in the present study works sufficiently because it is easily understandable and applicable due to its simplicity. But, additional discussion of the hierarchy among spatial concepts might be necessary if the taxonomy were applied in a different context.

Research Question 1b

How can tools of representation be categorized? There might be no objection to the idea that representations, as an essential component of spatial thinking, should be a primary dimension of a taxonomy of spatial thinking. The taxonomy of spatial thinking, constructed in this study, definitely reflected such emphasis on the importance of spatial representations by identifying Representation as one of the primary categories. The domain Representation is a distinctive feature distinguishing the taxonomy of spatial thinking from taxonomies of general thinking skills, which have rarely cared about tools of representation but only focused on the two dimensions – knowledge and cognitive domain.

A question that has to be answered is whether or not tools of representation can be classified. While concepts could be theoretically classified according to the complexity and abstractness, this was not the case with tools of representation. Neither was a framework developed to classify representations in terms of their complexity, nor did it seem possible or meaningful to do so. For example, suppose that there are three thematic world maps (i.e., a climate map, a religion map, and a population density map). According to what criteria can the three maps be classified? Which map is more complex or abstract than another? The problem of classification arises among different kinds of representations as well. For instance, is a diagram more complex or abstract than a map, or vise versa? Some might argue that the amount of information included in a representation can be a criterion to assess its complexity. Actually, such methods have often been used to evaluate student sketch maps. However, the effectiveness of a representation to help remember, understand, and communicate information may not always be proportional with the amount of information contained in the representation. Graphic efficacy, level of accompanying language, accuracy of the information, as well as the target population would also matter. In other words, classifying tools of representation by complexity can only be done within the contexts involving the purpose, audience, and types of information represented. Such considerations are beyond the research questions of this study, which is more concerned with whether or not the textbook questions encouraged students to practice using and creating a variety of representations rather than the specific characteristics of the representations.

In this study, only two subcategories were identified under the category Representation: Non-use of representation and Use of representation. The taxonomy enables one to distinguish the questions that encourage students to use or create a representation from the questions that do not. The two subcategories were sufficient to differentiate the potential of questions to support spatial thinking especially when combined with the subcategories of cognitive processes. One can characterize and classify textbook questions or test-like activities in a fairly detailed and reasonable way by using the combinations of the two categories: Representation and Cognitive Process. For example, a question asking students to simply recognize a fact from a graph will be characterized as Use of representation and Input. A question that requires comparisons of two maps will be categorized into Use of representation and Processing. If students are expected to infer from a paragraph, the question is classified into Non-use of representation and Processing. A question in which student are required to create a diagram to organize given data will be characterized as Use of representation and Output.

Research Question 1c

How can processes of reasoning be categorized? A body of literature was reviewed to understand reasoning processes and higher order thinking skills. Nine taxonomies of thinking skills (Anderson and Krathwohl 2001; Bloom et al. 1956; Costa 2001; Gouge and Yates 2002; Marzano 2001; Moseley et al. 2005; Presseisen 2001; Quellmalz 1987; Stahl and Murphy 1981) were considered in constructing a classification of cognitive processes.

This study adopted three classes of cognitive processes, following Costa's (2001) classification of the three levels of thinking: Input, Processing, and Output. The classification not only agreed with many taxonomies of thinking skills but also was the most intuitive and easily applicable to question analysis. The initial purpose of Costa's classification (2001) was to provide teachers with a guide to design questions to facilitate students' thinking. He argued that teachers should ask processing and output level questions more than input level questions to facilitate student thinking skills. Reasoning skills, one of the essential elements of spatial thinking, are considered higher order cognitive processes, such as analyzing, inferring, generalizing, and hypothesizing from given information rather than lower level of cognitive processes, such as defining, recalling, and recognizing information. Such reasoning skills can be developed by questions requiring cognitive processes at the processing and output level rather than at the input level. Previous research (Pizzini et al. 1992) assessing questions posed in middle school science textbooks used these categories thus confirming that the classification worked well in question analysis.

The cognitive processes in the taxonomy, however, must not be confused with the actual cognitive processes happening in the students' minds. The levels of cognitive processes required in a question need to be interpreted as objectives to be accomplished. That is, although the cognitive objective of a question was adequate to facilitate spatial thinking, that might not guarantee that every student achieved the cognitive skills required.

Implications

A valid taxonomy of spatial thinking was constructed, reflecting the three key components of spatial thinking. There have been several taxonomies of general thinking skills, but few of spatial thinking skills have been developed. Teachers and textbook publishers can use the taxonomy, developed in this study, as a guideline to incorporate appropriate level of spatial thinking into their lesson plans and the textbook features.

Teacher Education

Most pre- and in-service teachers are familiar with the Taxonomy of Educational Objectives proposed by Bloom et al. (1956). This study revealed that most taxonomies of general thinking skills, including Bloom's Taxonomy, are insufficient to provide an explicit guide for teaching spatial thinking skills. Teacher education system must equip teachers with knowledge about the nature of spatial thinking and understand how the three components are integrated for spatial thinking skills to be a powerful way of problem solving. Teachers should be given opportunities to figure out what are effective methods to teach a variety of spatial concepts; to learn how to use representations to facilitate students' thinking; and to become aware of cognitive processes desirable to develop spatial thinking skills. The taxonomy developed in this study can serve as a framework upon which teacher education programs to support spatial thinking can be built.

Teacher Practices

Teachers can use the taxonomy to diagnose their instruction and instructional materials in terms of: what concepts are emphasized or missed; whether spatial representations are used effectively; and on which level cognitive processes are focused. Based on such diagnoses, teachers will be able to improve their instruction, if needed, so that students can practice and learn a variety of spatial concepts, representations, and cognitive skills in a more explicit manner.

Using the taxonomy, teachers will be able to align their daily curricula by specific spatial concept, representation, and cognitive process rather than just by the textbook page order. For example, textbook sections dealing with the concept "connection and linkage" can be grouped for one or two class periods or be combined with a section addressing the concept "network" regardless of the textbook order. The foci of the activities are to understand ways many geographic features are connected to each other and to learn the meaning of a complex-spatial concept "network" more effectively. Students will be able to better understand and become more familiar with spatial concepts, particularly complex-spatial concepts, if instructions are organized around the concepts. Teachers also can facilitate students' reasoning skills by adopting behavioral objectives related to higher order thinking to their lesson objectives, assignments, and assessments more than those at the lower level. By combining such higher level cognitive objectives with a variety of spatial concepts and representations, teachers can more easily design class activities, assignments, as well as test-like events to support spatial thinking.

Design of Textbooks

Aspects of spatial thinking should be addressed in geography textbooks more explicitly. Textbook designers must understand the nature of spatial thinking, as a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning. The taxonomy developed in this study provides a framework that textbook publishers can refer to when incorporating three components of spatial thinking into the textbook features, particularly questions. The classification of each element enables textbook designers to monitor and ensure balance among different levels of concepts and cognitive processes featured in the textbook.

RESEARCH QUESTION 2: SPATIALITY OF TEXTBOOK QUESTIONS

Research Question 2a

What kinds of concepts are asked in the four high school geography textbooks? Concepts featured in the selected questions were categorized into the four subcategories: Non-spatial; Spatial-primitives; Simple-spatial; and Complex-spatial. As reported in Chapter IV, about 44 percent of 3,010 questions under study had nothing to do with spatial concepts; about 22 percent (679/3010) were about spatial-primitives; about 26 percent (748/ 3010) asked simple-spatial concepts; and complex-spatial concepts were asked only in about 9 percent of the questions (265/3010).

The results were not so disappointing because over half (56.21 percent, 1692/3010) required students to know spatial concepts. However, only 265 questions of 3,010 were associated with complex-spatial concepts. Complex-spatial concepts, such as distribution, pattern, network, hierarchy, and density, appear in our daily conversations, mass media, as well as at the workplace. To know and to be able to use these concepts help not only better understanding of a variety of phenomena in space but also provoke effective communications. The geography textbooks under study were high school level. Given that most of people have little chance to learn geographic concepts and ways of thinking in a formal educational setting after high school graduation, high school geography textbooks should help students learn what these spatial concepts mean and how to use them to describe and explain spatial phenomena.

The diversity of concepts within a level also needs to be ensured. The selected textbook questions focused on only a few spatial concepts rather than addressed a variety of spatial concepts. Place-specific identity was overwhelmingly asked among spatial primitives. Region was asked more than any other concepts within the category Simple-spatial concept. Distribution was most frequently featured among complex-spatial concepts, while spatial association, scale, network, and hierarchy rarely appeared. Understanding concepts, such as place, region, and distribution, must be important in learning geography. However, students should be given more opportunities to learn other spatial concepts, such as connection and linkage, movement, diffusion, and hierarchy, because they are critical concepts in geography as well (Gersmehl 2005).

Differences among Textbooks

Questions contained in Textbook C were the most spatial in terms of the concepts addressed (62.78 percent, 502/799), while those in Textbook A were the least (48.78 percent, 300/615). Textbook C also asked both the most simple-spatial and complex-spatial concepts, whereas Textbook A asked the least. The results might not happen by accident. Questions posed in a textbook would reflect the textbook's emphases on specific concepts, facts, theories and so forth. In addition, the emphases featured in the textbook would be influenced by the author's conceptualization of the subject matter. Therefore, the results can be interpreted that the writers of Textbook A valued the importance of spatial concepts in learning geography less than those of the other three books.

However, in many cases, those who make textbook questions are not the authors of the text. That is, the spatiality of a concept addressed in the textual content or other textbook features may not always be the same in degree as the spatiality of the concepts asked in the questions inserted in the book. Nevertheless, it is probably true that students will be able to understand and to practice to use spatial concepts better when such concepts are asked in the questions than when presented only in the textual content. If spatial concepts discussed in the textual content were never addressed in the textbook questions, these questions must be revised carefully so that they can be an effective method through which students can practice and learn spatial concepts.

Difference between Units: A Systematic Approach vs. A Regional Approach

Questions posed in Unit 2 asked spatial concepts more than those in Unit 1. As indicated in Chapter III, all four textbooks have almost the same organization and structure: the first unit takes a systematic approach to introduce geographic perspectives, methodologies, and general concepts; the second and following units take a regional approach presenting details on world regions. The result indicates that a regional approach can help learning spatial concepts more than a systematic approach to the subject matter of geography. However, such a conclusion should be a tentative one until more studies are conducted to compare a textbook that wholly adopts a regional approach with another that wholly approaches the subject systematically. The results of this study are limited because it compared two units within a textbook which mostly took a regional approach.

The percentages of questions related to complex-spatial concepts in both Unit 1 and Unit 2 were similar. The reason why questions posed in Unit 2 seemed more spatial than those in Unit 1 was that Unit 2 contained more questions asking place-specific identity and specific characteristics of regions than Unit 1. Knowing place names and remembering factual knowledge about a region cannot be the ultimate goal of learning geography or spatial thinking skills. Considering that the textbooks examined in this study took a regional approach in all units except the first unit, there might be few questions asking spatial concepts other than place and region throughout the textbooks. Thus, one may not argue that a regional approach to school geography always is more effective to teach spatial thinking skills than a systematic approach, only based on the number of spatial concepts featured. Instead, teachers should be able to improve their lessons taking a regional approach by incorporating a variety of spatial concepts rather than only focusing on place-specific identity and region.

Differences among Different Question Locations

In this study, categories of the question location mostly referred to the physical positioning of the question: In text; Page margin; Supplemental section; End of section; and End of chapter. Different locations also indicated different purposes of the question. Questions in text often appeared under a title such as *"Reading check*" and were intended to monitor student comprehension of the textual content. On the other hand, questions presented in the page margin were frequently termed *"Skill builder"*, *"Interpreting diagrams/maps/the visual record"*, and the like, emphasizing acquisition of skills more than knowledge comprehension. Questions provided at the end of sections and chapters were designed for comprehensive assessments that cover the overall knowledge and skills presented in the specific section or chapter, as represented in their titles *"Section assessment"* and *"Chapter assessment"*.

It is noteworthy that questions posed either at the end of a section or at the end of a chapter, the majority of the questions in all four textbooks, do not cover many important spatial concepts that students should know. Despite this fact, many teachers use these questions for assignments and refer to them to construct quizzes or assessment items. This might be because teachers believe these questions cover all critical knowledge and concepts that students should know, as the titles of the questions indicate. Thus, teachers might ignore questions posed in the page margin and supplemental sections if they believe they are less valuable.

This research found that spatial concepts most frequently appeared in the questions posed in page margins, while they appeared least in the questions at the end of sections. One exception was Textbook A, which asked non-spatial concepts most even in the page-margin questions. There was no special indication throughout the textbooks that the textbook publishers intended to address aspects of spatial thinking specifically in the page-margin questions. Nevertheless, one clear implication is that information about the spatiality of concepts addressed in questions based on their physical locations should help teachers to roughly choose a set of questions that will facilitate students' spatial thinking skills. In other words, if they want to use some of the textbook questions to aid students' learning of spatial concepts, teachers may have to select questions posed in page margins more than those posed in other locations.

Research Question 2b

Do the questions require students to use and create spatial representations? This research question examined whether or not the selected textbook questions asked students to use or produce a spatial representation to answer the questions. Every question was categorized into the two subcategories: Non-use of representation and Use of representation. About 70 percent of 3,010 questions had nothing to do with using a given representation or creating a new one. Taking into consideration that the ability to interpret and create spatial representations is critical to be a competent spatial thinker (NRC 2006), the potential of the questions to provide students with opportunities to practice such skills seems low.

All four textbooks examined include an incredible number of maps, diagrams, photos, or graphs on almost every page. However, the study results suggested that, despite the prevalence, the rich array of representations inserted in the textbooks was not fully utilized to facilitate students' spatial thinking skills. Representations were seldom connected to student practices, such as answering the textbook question to review the content, check their knowledge comprehension, and practice thinking skills. Recalling Lord's (1985) point that skills to understand, use, and make spatial representations can only be enhanced through exercises in a variety of contexts, more textbook questions are needed though which students can practice to use a variety of spatial representations provided in geography textbooks.

It has to be noted that there were particularly few questions asking students to create a spatial representation as a tool to transform, visualize, and report information.

Rather, many questions asked students to label a diagram and fill out an empty table or a map, although they were titled *"Creating a graphic organizer"*. These questions only required students to regurgitate information presented in the text by filling in the provided blanks. They did not elicit the students' efforts to creatively organize and visualize information through a tool of representation as well as to utilize it as an effective means of communication. It is probably due to the lack of understanding of the question makers about the role of representations as a powerful tool of thinking or the lack of familiarity with the technique to connect geographic knowledge and skills to spatial representations. This might be similar to the situation noted by Bednarz (2004) that teachers who had not been taught with maps lacked the skill to utilize maps in their own classes (Bednarz 2004). For whatever reasons, and as Mathewson (1999) argued, questions such as the traditional labeling of a diagram is insufficient as a means of assessing in-depth understanding of spatial relationships represented in the diagram. As such, labeling a blank map and filling out a table can hardly be a good practice for enhancing students' skills to effectively use and create spatial representations. Those who make textbook questions must understand the variety of roles representations, as powerful tools of thinking and communication, play and be able to design questions through which students practice and learn to think with representations in more effective ways.

Differences among Textbooks

Questions included in Textbook A were the most spatial in terms of representations, while those in Textbook C were the least. The result was exactly opposite to the spatiality of the concepts in that Textbook C addressed spatial concepts most and Textbook A least. The results suggest that when comparing the spatiality of textbooks, one should not judge from only one aspect (i.e., concepts of space, tools of representation, or reasoning processes) but from multiple aspects.

Differences among Different Question Locations

Over 70 percent of in text questions did not require students to use a representation. In contrast, about 98 percent of the questions in page margins asked students to use representations. As noted in the discussion about concepts, the result should be contextualized within the purpose of the questions in different locations. For example, the question inserted in the textual content was supposed to provide students with opportunities to check their comprehension of the textual content, not to monitor skills of using representations. Actually, the latter role was played well by page margin questions.

A concern arises for the section and chapter assessment questions. The results suggest that the section and chapter assessment questions would seldom help students practice and learn the key component of spatial thinking – tools of representation. Over 90 percent of the questions designed for the section assessment had little to do with using spatial representations. Neither did over 70 percent of the questions posed at the end of chapter. These questions were supposed to comprehensively address knowledge and skills that students are expected to learn in geography classes. Nevertheless, those huge numbers of questions overlooked skills to use and create spatial representations but only focused on memorized knowledge of terms, generalizations, and main ideas presented in the textual content.

Teachers would be well advised to organize classroom activities around page margin questions more than section assessment or chapter assessment questions to facilitate students' skills to use tools of representations. Question designers must recognize the significance of skills to use spatial representations in learning geography as well as in the development of spatial thinking and make the assessment questions incorporate more spatial representations.

Research Question 2c

What kinds of cognitive processes are required to answer the questions? This research question concerned whether or not the textbook questions stimulate students' reasoning. Psychologists have agreed that reasoning is a high order cognitive process, and educational psychologists have identified behavioral objectives to provoke such high levels of cognition in the student mind. Since there was no way to directly measure whether a textbook question actually stimulates reasoning in the student brain, this study examined the behavioral objectives featured in the questions and determined the degree of stimuli for reasoning, based on the frequency of each level of the cognitive objectives. Three levels of cognitive process categories were used in this study: Input, Processing and Output, following Costa's (2001) conceptualization.

Processes of reasoning considered the core of spatial thinking require multiple transforms of representations as well as making inferences from them (NRC 2006).

Therefore, it may be especially true that spatial thinking cannot be accomplished only with abilities to recall memorized factual knowledge, although such knowledge constitutes a part of reasoning. This study assumed that questions that require students to process and transform given information (processing level) and to generate new knowledge from generalizations, prediction, and hypothesis (output level) are more desirable to facilitate spatial thinking skills than those that require only recalling information and recognition of facts (input level).

About 60 percent of 3,010 questions required cognitive processes at the input level. The three most common cognitive processes were defining, identifying, and matching. Questions requiring processing and output levels of thinking were about 29 percent and 13 percent, respectively. Over a decade ago, Bednarz and Peterson (1994) pointed out that much of the available geography educational materials require only low level thinking. As for textbook questions, it seems still true. The results of the present study indicate that the geography textbook questions emphasize student abilities to recall memorized knowledge more than application, inference from, and generalization from given information. It is noteworthy that the results were quite different from a similar study by Marran (1995) on the behavioral objectives featured in the National Geography Standards. According to Marran, the most frequently featured verbs in the Standards activity statements were ‘explain’ and ‘analyze’, which are at the processing level of thinking. ‘Evaluate’ and ‘apply’ followed next, which are output level of cognitive processes.

The difference between Marran's results and the result of the present study implies that the efforts and expectations of the Standards to facilitate students' higher order thinking and problem solving skills have not been fully implemented into high school geography textbook questions. The spirit and expectations of the Standards should be infused into textbook questions as well as other textbook features. Question designers have to understand the cognitive objectives proposed in the Standards and make questions that are an effective method for students to achieve such objectives.

Differences among Textbooks

Textbook C was evaluated the highest in the level of the cognitive processes required in the questions, with about 51 percent of 799 questions requiring either processing or output level. Textbook D followed (47.42 percent, 312/658). However, the most frequently required cognitive process in all four textbooks was 'defining'. What determined the differences among the four books was the second or the third most required thinking process. That is, the reason that Textbook C was highly evaluated was because the book included a fairly large number of questions requiring students to 'evaluate', and Textbook D contained many 'inferring' questions. Meanwhile, all the three most frequently required cognitive processes in the questions of Textbooks A and B were input level ('defining', 'matching', and 'identifying' for Textbook A; 'defining', 'listing', and 'matching' for Textbook B).

Difference between Units: A Systematic Approach vs. A Regional Approach

Unit 2 contained more questions having to do with higher levels of thinking than Unit 1. The most frequently required cognitive processes in the questions posed in Unit 1 were defining, identifying, listing, matching, and inferring; in Unit 2 they were defining, identifying, evaluating, inferring, and comparing.

Evidence is insufficient that this pattern was due to the difference of the approach to the subject matter of geography that each unit took: a systematic approach or a regional approach. It is possible though that the question makers felt that making comparison or evaluation questions from the content presented in Unit 2 was relatively easier than from the content presented in Unit 1 because Unit 2 included geographic features of a region to be compared with another region (i.e., climate, culture, language, and religions) more than Unit 1. Perhaps, the questions posed in Unit 2 simply reflect the emphasis on knowing similarities and differences among different places and regions in a regional approach of geography. For whatever reasons, teachers should be able to maximize the potential of the questions posed in units taking a regional approach to facilitate students' higher level cognitive skills.

Differences among Different Question Locations

Over 60 percent out of 1,131 section-assessment questions required students to define terms, identify or list facts and generalizations. Meanwhile, over 60 percent of 375 questions located at the page margin required processing or output level of thinking. Page-margin questions would help the development of higher order thinking skills more than section assessment questions. The reason that page-margin questions were highly related to higher level cognitive processes can be understood with respect to the degree to which questions in the location required using representations. As pointed out previously, over 90 percent of the page-margin questions were linked to using representations. Representations are a powerful tool to organize, summarize, as well as remember a complex set of data. One should be able to interpret and understand the information and relationships presented in a representation to properly use the representation for problem solving. Producing a quality representation may require even higher cognitive skills than just using a given representation. That is, if a question asked students to use or produce a representation, it means that the question had to be answered after the students had completed more complex cognitive processes, such as organizing, summarizing, and comparing, than reciting, recognizing, and the like.

A recent report about spatial thinking by National Research Council (2006) pointed out that the processes of spatial reasoning often begin with using spatial representations. The present research also found that many questions related to using a variety of spatial representations were related to higher level cognitive processes desired to facilitate spatial thinking. Although not always, teachers will be able to make students think at the higher level by using questions that accompany representations even without scrutiny of the questions' cognitive objectives.

Research Question 2d

Do the textbook questions integrate the three components of spatial thinking? This study intended not only to examine the degree to which each component of spatial thinking was addressed in the selected textbook questions but also to evaluate the degree to which these three components were integrated into the questions. The second part of the research question was important because it may be insufficient for a person just to know spatial concepts, or be able to interpret spatial representations, or be capable of reasoning to be a competent spatial thinker. A question that fully supports the development of spatial thinking skills, therefore, should enable students to incorporate all three of the components in the process of answering a question rather than to use only one of these components.

The results showed that about 76 percent of 3,010 questions did not integrate three components. Many questions focused on only one or two components of spatial thinking, or asked knowledge or skills irrelevant to spatial thinking. Students were not provided with adequate opportunities to integrate spatial concepts, tools of representation, and reasoning processes to answer the questions. Both teachers and question designers must understand the nature of spatial thinking, which is a constructive amalgam of three components. Question makers have to integrate the key three components into the questions. To facilitate students' spatial thinking skills, teachers should monitor their instructions, instructional materials, as well as questions to integrate the three components effectively.

It should be noted that the majority of the 'integrated' questions fell into Cells 10, 11, and 16, which represented the simplest level of spatial thinking. Students should be given more opportunities to practice and learn higher level spatial thinking. One strategy that teachers can use is to make students answer challenging questions and engage in projects that require such higher level concepts and cognitive processes. However, the creation of challenging projects is often overwhelming to individual teachers. Textbook publishers should support it.

Differences among Textbooks

It is noteworthy that Textbook A included more questions incorporating the three components than any other textbook. At the same time, it contained the fewest questions regarding spatial concepts and scored almost the lowest in the levels cognitive processes required. This occurred in part because questions related to input level of cognitive process were not excluded even though the cognitive process itself is far from reasoning. The reason that input levels of cognition were also counted was that processing and output levels were actually built on input levels of cognitive processes. Therefore, as long as a question is connected with both spatial concepts and representations, the question can account for the most basic level of spatial thinking.

The rank of the textbooks would change if input levels of thinking were excluded. Textbook D would be ranked first, and Textbook A would be last. Nevertheless, the result is still interesting because Textbook C, where questions addressing spatial concepts and higher order thinking processes were featured most, was not ranked first. This result confirmed that three components of spatial thinking were addressed individually in the questions rather than in an integrated form. It also confirmed that the potential of the textbook questions to support spatial thinking should be judged from multiple criteria not from one.

Difference between Units: A Systematic Approach vs. A Regional Approach

The questions posed in Unit 2 incorporated the three components of spatial thinking more than those in Unit 1 although over 60 percent of questions in both units were classified as ‘not integrated’. The result would be the same even if the questions related to input levels of cognition were excluded. Therefore, students would be provided with relatively more opportunities to practice incorporating the three components of spatial thinking when answering questions posed in Unit 2 than when answering questions in Unit 1.

Differences among the Different Question Locations

The degree to which three components of spatial thinking were integrated was quite different by question location. As mentioned, the majority of the textbook questions was posed at the end of a section or the chapter (2207 out of 3010), and these questions were supposed to encompass all critical knowledge and skills that should be learned by students. If these questions are frequently referred to and used by individual teachers, the spatiality of these questions is really important to support students' spatial thinking skills. These questions must be able to help students practice integrating the three components of spatial thinking. The results, however, show that over 90 percent of the questions at the end of sections and about 80 percent of those at the end of chapters were categorized as Not-integrated. On the other hand, about 75 percent of the 375 questions posed in page margins and about 53 percent of 243 supplemental-section questions required students to know spatial concepts, to use or create a spatial representation, as well as to reason with them.

Whether or not intended by the question makers, many of the skills intended to be learned from page-margin questions are spatial thinking skills. In terms of the degree to which the three components of spatial thinking were addressed, page-margin and supplemental section questions were better than section- and chapter assessment questions in general. To support spatial thinking through practice with questions, therefore, teachers should frequently use questions posed in page margins and supplemental sections, which might have often been ignored. Question makers must realize that questions at the end of sections and chapters do little to develop one of the important skills to be taught in geography - spatial thinking – and make more effort to incorporate the three components of spatial thinking into these questions.

Implications

Use of Textbook Questions

This study examined the spatiality of the questions posed in four high school geography textbooks currently used in Texas. Many questions focused on non-spatial concepts and relatively simple concepts rather than complex-spatial concepts. There were not many questions that required students to use and create spatial representations. Most questions examined in this study required low level cognitive processes, such as defining, recalling, and recognizing. These results suggest that, to facilitate students' spatial thinking skills, teachers should use textbook questions selectively and cautiously. Teachers should be able to distinguish questions that effectively address aspects of spatial thinking from those that do not.

One clear implication of the study is that teachers must not ignore questions posed in the page margin, but rather frequently use them. Page-margin questions addressed all the three components of spatial thinking most often. Far more questions in the page margin required using spatial representations and higher level cognitive processes. It might be true that many teachers have not paid attention to the questions in the page margin as much as to the questions presented at the end of sections and chapters. The reason could be because they believe the questions at the end of sections and chapters cover all critical knowledge and skills to be learned; and page-margin questions are just supplemental. However, questions posed at the end of sections and end of chapters did little to incorporate aspects of spatial thinking, which means these questions neglect spatial thinking skills.

The results of the study also indicate that using textbook questions may hardly contribute to students' learning of complex-spatial concepts. In addition, students may not practice and learn the skills necessary to produce representations effectively by answering textbook questions. Textbook questions may not contribute to the development of higher order thinking skills, either. In addition to using the questions presented in the textbook selectively, teachers should be able to design questions of their own, through which students can learn a variety of complex-spatial concepts, skills to create spatial representations to remember, transform, and communicate information more effectively, as well as higher level cognitive processes. Teachers can use the taxonomy developed in this study as a guide to design such questions.

Design of Textbook Questions

This study provided evidence that spatial concepts, such as pattern, diffusion, hierarchy, and network, were rarely addressed in the textbook questions. Understanding such concepts is critical in our daily lives as well as at the work place, but students are neither provided with sufficient opportunities to learn these important spatial concepts nor asked to monitor their knowledge about such concepts through answering questions. Textbook publishers need to ensure these concepts are addressed in their question sets.

This study also revealed that most questions focused only on a few concepts, particularly place-specific identity and region. The situation was evident in Unit 2, taking a regional approach, more than in Unit 1, which takes a systematic approach. Considering that the textbooks examined in this study are used for World Geography Studies courses and that all units except Unit 1 take a regional approach, students may not be given sufficient opportunities to learn spatial concepts than place-specific identity and region when learning from these textbooks. Textbook publishers have to ensure the diversity of the concepts asked in geography textbooks.

The geography textbooks under study included a number of graphics and spatial representations. This study showed, however, that students did not need to use these representations to answer the textbook questions. Questions did not fully utilize the rich array of graphics provided in the textbooks to support spatial thinking. In order for the questions to support spatial thinking, they should guide students to learn how to use a variety of representations to obtain, transform, and communicate information more effectively. Questions asking only to fill in a blank map may not play such roles. Textbook designers must be aware that representations are a powerful tool of thinking not just a container of information.

The present study provided evidence that the higher order thinking skills emphasized in the Standards, such as analyzing, explaining, and evaluating, have hardly been implemented into textbook questions. To support spatial thinking, the spirit and expectations of the Standards should be infused into textbook questions as well as other textbook features. Question designers should be aware of the cognitive objectives proposed in the Standards and make efforts to address such objectives in the textbook questions more explicitly so that students can practice higher level of thinking skills through answering the questions.

Spatial thinking is a complex form of thinking that requires knowledge about spatial concepts, using tools of representations, as well as reasoning processes. For a person to be a competent spatial thinker, the person should be equipped with knowledge about a variety of spatial concepts, abilities to use spatial representations in appropriate and effective ways, and reasoning skills. Therefore, questions that require students to incorporate all of the three components of spatial thinking are desirable to develop spatial thinking skills more than those related to only one component. This study revealed that the three components of spatial thinking were not integrated in the majority of the questions examined. More questions need to be developed that guide students to synthesize the three components.

If the low spatiality of the textbook questions was because textbook publishers had not cared about the quality of textbook questions as much as about other features of textbooks, such as the accuracy of textual content and aesthetic elements of the visual resources, such practice should be discouraged. In other words, if aspects of spatial thinking addressed in the textual content or other textbook features are never addressed in the textbook questions, these questions must be revised carefully so that they can be an effective method through which students can practice and learn spatial concepts.

Evaluation of Textbooks

Textbook research should help teachers' textbook choices by providing sufficient information about a variety of textbook features. This study provided in-depth analyses of the spatiality of the questions posed in four high school world geography textbooks. To the teachers who value textbook questions, such information will be useful to compare the characteristics of questions in different textbooks and to select the book whose questions satisfy their educational emphases most. In addition, teachers can examine what are the strengths and weaknesses of the questions posed in the textbook that they currently use. Findings from such examinations will allow teachers to use textbook questions to empower their strengths and compensate for their weaknesses.

SUMMARY AND CONCLUSIONS

Summary

Geographers have been concerned about spatial perspectives. The importance of spatial thinking skills is manifested in the National Geography Standards (1994) as well. However, there has been little research on whether geography textbook features incorporate such important skills. Neither have valid criteria been developed that can be used for such an examination.

The objective of this study was to evaluate the spatiality of questions posed in four high school world geography textbooks in terms of the three components of spatial thinking: concepts of space, tools of representation, and processes of reasoning. Two major research questions were:

1. How can aspects of spatial thinking be categorized?

2. What concepts, tools, and cognitive processes are required to answer the questions posed in four high school world geography textbooks?

The first research question resulted in the establishment of a taxonomy of spatial thinking that can be used to assess textbook questions in terms of the three components of spatial thinking. Three primary categories of the taxonomy were derived from the definition of spatial thinking as “a constructive amalgam of concepts of space, tools of representation, and processes of reasoning” (NRC 2006): Concept; Representation; and Cognitive Process. The subcategories of each primary category were based on theories of thinking skills and classifications of spatial concepts presented in previous research. As a result, Non-spatial, Spatial primitives, Simple-spatial, and Complex-spatial were identified as the four subcategories of the first primary category – Concept; two subcategories, Non-use of representations and Use of representations, constituted the second primary category – Representation; and Input, Processing and Output comprised of the third primary category – Cognitive Process.

The second research question evaluated the degree to which the selected textbook questions incorporate the three components of spatial thinking. A total of 3,010 questions posed in the first two units of the four high school world geography textbooks used in Texas were examined. Unit 1 and 2 were purposely selected to compare the spatiality of the questions posed in units that approach the subject matter of geography differently – a systematic approach and a regional approach. Every question was compared against the taxonomy and assessed in terms of the spatiality of the concepts asked, the degree to which representations are used, and the level of cognitive processes required. Differences among the four textbooks, between the two units, and among the five question locations were also determined.

Conclusions

First, a valid taxonomy of spatial thinking was constructed, that reflects the three key components of spatial thinking in its three-dimensional structure. There have been several taxonomies of general thinking skills, but few of spatial thinking skills. The taxonomy can serve as a criterion upon which teachers diagnose and improve their lessons, instructional materials, as well as evaluate textbook questions in terms of aspects of spatial thinking. The taxonomy also can guide textbook publishers to incorporate the three components of spatial thinking into their textbook features in more explicit and systematic ways.

Second, this study recognized that the textbook questions did little to address complex-spatial concepts. In addition, this study found that the questions focused on only a few concepts rather than a variety of spatial concepts. Textbook publishers need to make an effort to address more complex-spatial concepts in their question sets. Teachers, on the other hand, should be able to design their own questions that address a variety of complex-spatial concepts rather than relying only on the questions given in the textbook. The diversity of concepts taught in geography classes should be ensured both by individual teachers as well as textbook designers.

Third, this study found that textbook questions did little to utilize the rich array of graphics provided in the textbooks. Textbook publishers need to make more questions connected to a variety of representations so that students can practice skills to use and create representations. In addition, teachers and textbook publishers must understand that spatial representations contribute to the development of students' spatial thinking skills only when combined with activities to elicit higher level cognitive processes. Activities that ask students only to recognize and memorize information presented in representations are insufficient to elicit such higher order thinking.

Fourth, this study provided evidence that the expectations of the Standards for higher order thinking skills have seldom been implemented into the textbook questions. Many questions focused more on input levels of cognitive processes rather than the cognitive processes at the processing and output level. More efforts need to be made by textbook publishers to infuse the spirit and expectations of the Standards into textbook questions as well as other textbook features.

Fifth, most questions lacked integration of three components of spatial thinking. Spatial thinking is a complex form of thinking that requires knowledge about spatial concepts, using tools of representations, as well as reasoning processes. More questions to integrate the three components need to be developed. When using textbook questions to teach spatial thinking, teachers have to ensure their students to practice to integrate three components rather than to focus on only one or two components.

Sixth, this study found that the spatiality of the questions varied by question location. In general, questions posed in the page margin and supplemental sections addressed the three components of spatial thinking more than those posed at the end of sections and chapters. Thus, page-margin questions should not be ignored or marginalized in learning from geography textbooks.

Finally, this study was almost the first attempt to analyze geography textbook questions, an untouched area in geography education research. There have been few studies on geography textbooks, and little research focused on specific features of a textbook, such as review questions, suggested activities, and study guides for students. These are important components of a textbook which teachers and students frequently use but have been neglected in the literature. Textbook research has to address such textbook features as well. In addition, the present study focused wholly on the three key aspects of spatial thinking addressed in geography textbooks. There have been a few studies that examined implementation of the Standards in general, but little research was conducted on a specific element of the subject matter – spatial thinking - in such a detail. Teachers will benefit from such concrete information about the textbooks when comparing the strengths and weaknesses of each textbook and selecting a book that satisfies their educational objectives and emphases most.

SUGGESTIONS FOR FUTURE RESEARCH

The present study explored a relatively untouched area in the field: geography textbooks, textbook questions, and the incorporation of spatial thinking into school geography. The criteria of the evaluation and data analyses frameworks were, therefore, fairly innovative. Future research extended from this initial study would improve the accuracy of the results, refine the methodology, and reinforce the findings of the study.

This study identified three different levels of spatial thinking according to the level of concepts and cognitive processes associated with: Cells 10, 11, and 16; Cells 12, 17, and 22; and Cells 18, 23, and 24. For example, questions requiring knowledge about complex-spatial concepts and higher level cognitive processes, categorized into Cells 18, 23, and 24, were considered more complex, abstract, and difficult than questions requiring spatial primitives and lower level of cognition, classified into Cells 10, 11, and 16. This classification was based only on the structure of and the hierarchies identified in the taxonomy rather than empirical evidence. Research needs to investigate whether the hierarchies are also valid in reality.

Regarding the level of spatial thinking, the question also needs to be answered: Is mastering simpler level spatial thinking tasks a prerequisite for learning more complex level spatial thinking tasks? Or, do practices with questions asking complex level spatial thinking also enhance students' performances on questions requiring simple level spatial thinking? There have been some studies in other subject areas showing that practice with questions requiring higher levels of cognitive process also facilitated student performance on questions requiring relatively lower level cognition. For example, students who practiced with questions asking them to apply mathematical principles to answer a question also performed well on questions asking them simply to calculate (Mayer 1975; Watts and Anderson 1971). The results were extended to argue that practicing with higher cognitive level questions should be encouraged. It is worth examining whether such a premise is also valid for the development of spatial thinking.

Third, this study assumed that teachers use textbook questions to provide students with opportunities to check their knowledge and skills learned from the text. However, there has been no research on how and for which purposes teachers actually use the questions in their instructions. In which location are the questions teachers use most often? Why do they more frequently use those questions than others? What do teachers expect students to learn from those questions? These questions should be answered in future research to better understand teacher practices with respect to textbook questions as well as to improve textbook questions so that they can contribute to students' learning.

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APPENDIX A

TAXONOMY VALIDATION SURVEY

This survey asks your opinion on the appearance and content of a spatial thinking taxonomy. The purpose of the survey is to achieve face validity and content validity for the taxonomy from expert judges.

Terms:

- Face validity: The extent to which the taxonomy looks like a measure of aspects of spatial thinking
- Content validity: The degree to which the categories of the taxonomy represent aspects of spatial thinking identified in the definition

Definition of Taxonomy:

A system of classification and the concepts underlying it (Good 1973)

Definition of Spatial Thinking:

A collection of cognitive skills consisting of knowing concepts of space, using tools of representation, and reasoning processes (NRC 2006)

Directions:

Please examine Taxonomy of Spatial Thinking on the next page and answer the following 10 questions. Rate aspects of the taxonomy on a 1 to 5 scale and then circle your response to the items.
(1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree)

11. Does the taxonomy seem to be measuring aspects of spatial thinking?	1 2 3 4 5
12. Does the taxonomy seem like a reasonable way to gain the information about whether geographic instructional materials incorporate three components of spatial thinking?	1 2 3 4 5
13. Does the taxonomy seem as though it will work reliably?	1 2 3 4 5
14. Does the taxonomy reflect the definition of spatial thinking?	1 2 3 4 5
15. Does the taxonomy reflect three key components of spatial thinking?	1 2 3 4 5
16. Are the concepts of space representative?	1 2 3 4 5
17. Are the cognitive processes representative?	1 2 3 4 5
18. Is the classification of concepts appropriate?	1 2 3 4 5
19. Is the classification of representation appropriate?	1 2 3 4 5
20. Is the classification of cognitive processes appropriate?	1 2 3 4 5

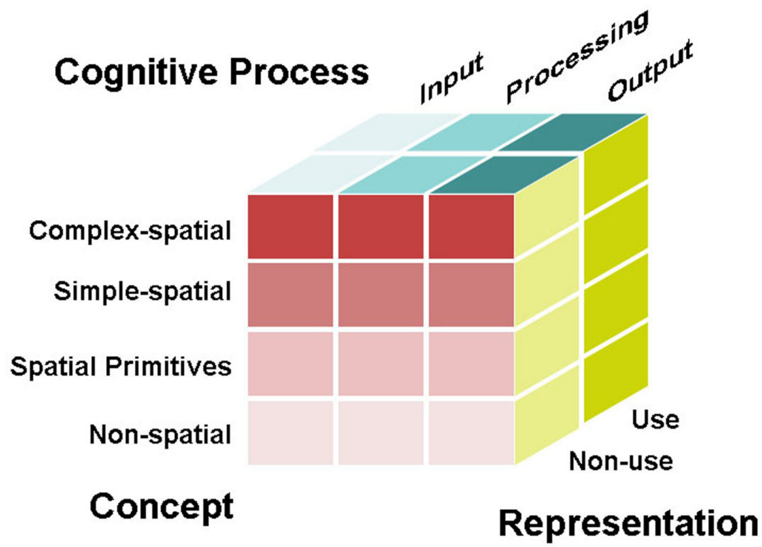
TAXONOMY OF SPATIAL THINKING

3: Complex-Spatial
Distribution
Pattern
Dispersion & Clustering
Density
Diffusion
Dominance
Hierarchy & Network
Spatial Association
Overlay
Layer
Gradient
Profile
Relief
Scale
Map Projection

2: Simple-Spatial
Distance
Direction
Connection & Linkage
Movement
Transition
Boundary
Region
Shape
Reference Frame
Arrangement
Adjacency
Enclosure

1: Primitives
Place-specific Identity
Location
Magnitude

0: Non-spatial



1: Input
Name
Define
List,
Identify
Recognize
Recite
Recall
Observe
Describe
Select
Complete
Count
Match

2: Processing
Explain
Analyze
State causality
Compare
Contrast
Distinguish
Classify
Categorize
Organize
Summarize
Synthesize
Infer
Make analogies
Exemplify
Experiment
Sequence

3: Output
Evaluate
Judge
Predict
Forcast
Hypothesize
Speculate
Plan
Create
Design
Invent
Imagine
Generalize
Build a model
Apply a principle

1: Use
Map
Diagram
Chart
Graph
Photo

0: Non-use

APPENDIX B

INSTRUCTIONS FOR THE QUESTION ANALYSIS

[Objective]

The objective of the study is to evaluate the spatiality of questions posed in high school-level world geography textbooks through the examination of the concepts, representations, and cognitive processes that the questions require.

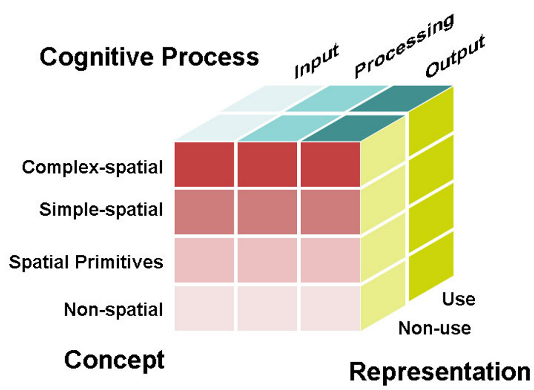
[Criteria for the Analysis: Taxonomy of Spatial Thinking]

3: Complex-Spatial
Distribution
Pattern
Dispersion & Clustering
Density
Diffusion
Dominance
Hierarchy & Network
Spatial Association
Overlay
Layer
Gradient
Profile
Relief
Scale
Map Projection

2: Simple-Spatial
Distance
Direction
Connection & Linkage
Movement
Transition
Boundary
Region
Shape
Reference Frame
Arrangement
Adjacency
Enclosure

1: Primitives
Place-specific Identity
Location
Magnitude

0: Non-spatial



1: Input	2: Processing	3: Output
Name	Explain	Evaluate
Define	Analyze	Judge
List,	State causality	Predict
Identify	Compare	Forcast
Recognize	Contrast	Hypothesize
Recite	Distinguish	Speculate
Recall	Classify	Plan
Observe	Categorize	Create
Describe	Organize	Design
Select	Summarize	Invent
Complete	Synthesize	Imagine
Count	Infer	Generalize
Match	Make analogies	Build a model
	Exemplify	Apply a principl
	Experiment	
	Sequence	

1: Use
Map
Diagram
Chart
Graph
Photo

0: Non-use

[Instructions for Question Coding]

<u>Basic questions to be kept in mind</u>

- What concepts does the question require the student to know?
- Does the question ask to use or produce a spatial representation?
- What level of cognitive process does the question require?

Examples

Example A

▪ Question: This field of icebergs creates a beautiful, if eerie landscape. Icebergs are large, floating masses of ice that have broken away from glaciers. In what regions are you most likely to find icebergs?

(Kracht 2003, 14)

▪ Answer: Icebergs would most likely to be found in Polar Regions where it is very cold.

▪ Coding:

1. What concepts does the question require students to know?
   1) Is it spatial? Yes/ No (Non-spatial=0)
   2) If Yes, is the concept spatial primitive (=1), simple-spatial (=2), or complex-spatial (=3)? When multiple concepts are asked, rate the question according to more complex concept.
2. Does the question ask students to use or produce a spatial representation to answer the question? No (Non-use of representations=0)/ Yes (Use of representations=1)
3. What level of cognitive process does the question require?
   1) Is it related to cognitive processes of Input level? Yes (Input=1)/ No
   2) Or, is it related to cognitive processes of Processing level? Yes (Processing=2)/ No
   3) Or, is it related to cognitive processes of Output level? Yes (Output=3)/ No

Concept	Representation	Cognitive Process
0 1 2 3	0 1	1 2 3

Example B

▪ Question: Define nonrenewable resource. (Kracht 2003, 33)

▪ Answer: A material that cannot be replaced once it is used up

▪ Coding:

1. What concepts does the question require students to know?
   1) Is it spatial? Yes/ No (Non-spatial=0)
   2) If Yes, is the concept spatial primitive (=1), simple-spatial (=2), or complex-spatial (=3)? When multiple concepts are asked, rate the question according to more complex concept.
2. Does the question ask students to use or produce a spatial representation to answer the question? No (Non-use of representations=0)/ Yes (Use of representations=1)
3. What level of cognitive process does the question require?
   1) Is it related to cognitive processes of Input level? Yes (Input=1)/ No
   2) Or, is it related to cognitive processes of Processing level? Yes (Processing=2)/ No
   3) Or, is it related to cognitive processes of Output level? Yes (Output=3)/ No

Concept	Representation	Cognitive Process
0 1 2 3	0 1	1 2 3

Example C

▪ Question : Why is the Earth's population growing faster now than in the past? (Kracht 2003, 43)

▪ Answer: People are healthier, birthrates are higher, death rates are lower, and there is a more abundant food supply.

▪ Coding:

1. What concepts does the question require students to know?
   1) Is it spatial? Yes/ No (Non-spatial=0)
   2) If Yes, is the concept spatial primitive (=1), simple-spatial (=2), or complex-spatial (=3)? When multiple concepts are asked, rate the question according to more complex concept.
2. Does the question ask students to use or produce a spatial representation to answer the question?
   No (Non-use of representations=0)/ Yes (Use of representations=1)
3. What level of cognitive process does the question require?
   1) Is it related to cognitive processes of Input level? Yes (Input=1)/ No
   2) Or, is it related to cognitive processes of Processing level? Yes (Processing=2)/ No
   3) Or, is it related to cognitive processes of Output level? Yes (Output=3)/ No

Concept	Representation	Cognitive Process
0 1 2 3	0 1	1 2 3

Example D

▪ Question: Since 1959, about one million Cubans have fled their communist-ruled country to find a new life in the United States. Many have settled in Florida. Use the map scale to determine about how far Cuba lies from the mainland of Florida. (Kracht 2003, 45)

▪ Answer: Cuba lies about 150 miles (240 km).

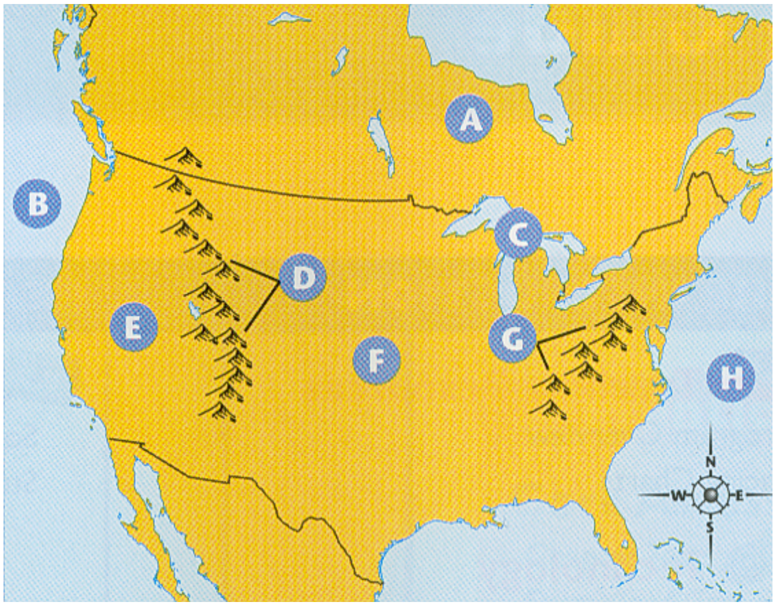
▪ Coding:

1. What concepts does the question require students to know?
   1) Is it spatial? Yes/ No (Non-spatial=0)
   2) If Yes, is the concept spatial primitive (=1), simple-spatial (=2), or complex-spatial (=3)? When multiple concepts are asked, rate the question according to more complex concept.
2. Does the question ask students to use or produce a spatial representation to answer the question?
   No (Non-use of representations=0)/ Yes (Use of representations=1)
3. What level of cognitive process does the question require?
   1) Is it related to cognitive processes of Input level? Yes (Input=1)/ No
   2) Or, is it related to cognitive processes of Processing level? Yes (Processing=2)/ No
   3) Or, is it related to cognitive processes of Output level? Yes (Output=3)/ No

Concept	Representation	Cognitive Process
0 1 2 3	0 1	1 2 3

Example E

▪ Question: For each place listed below, write the letter on the map that shows its location. Use the Atlas at the back of the book to complete the exercise. (Kracht 2003, 85)



1) Canadian Shield
2) Great Basin
3) Great Plain
4) Rocky Mountain
5) Appalachian Mountains
6) Appalachian Mountains
7) Pacific Ocean
8) Atlantic Ocean
9) Great Lakes

▪ Answer: 1) – A; 2) – E; 3) – F; 4) – D; 5) – G; 6) – B; 7) – H; 8) – C

▪ Coding:

1. What concepts does the question require students to know?
   1) Is it spatial? Yes/ No (Non-spatial=0)
   2) If Yes, is the concept spatial primitive (=1), simple-spatial (=2), or complex-spatial (=3)? When multiple concepts are asked, rate the question according to more complex concept.
2. Does the question ask students to use or produce a spatial representation to answer the question? No (Non-use of representations=0)/ Yes (Use of representations=1)
3. What level of cognitive process does the question require?
   1) Is it related to cognitive processes of Input level? Yes (Input=1)/ No
   2) Or, is it related to cognitive processes of Processing level? Yes (Processing=2)/ No
   3) Or, is it related to cognitive processes of Output level? Yes (Output=3)/ No

Concept	Representation	Cognitive Process
0 1 2 3	0 1	1 2 3

APPENDIX C

ANALYSIS ON THE SPATIALITY OF TEXTBOOK QUESTIONS

Coder Information

Name: ______________________________

Position: ______________________________

Academic field: ______________________________

Answer sheet

No.	Concept	Representation	Cognitive Process
1	0 1 2 3	0 1	1 2 3
2	0 1 2 3	0 1	1 2 3
3	0 1 2 3	0 1	1 2 3
4	0 1 2 3	0 1	1 2 3
5	0 1 2 3	0 1	1 2 3
6	0 1 2 3	0 1	1 2 3
7	0 1 2 3	0 1	1 2 3
8	0 1 2 3	0 1	1 2 3
9	0 1 2 3	0 1	1 2 3
10	0 1 2 3	0 1	1 2 3
11	0 1 2 3	0 1	1 2 3
12	0 1 2 3	0 1	1 2 3
13	0 1 2 3	0 1	1 2 3
14	0 1 2 3	0 1	1 2 3
15	0 1 2 3	0 1	1 2 3
16	0 1 2 3	0 1	1 2 3
17	0 1 2 3	0 1	1 2 3
18	0 1 2 3	0 1	1 2 3
19	0 1 2 3	0 1	1 2 3
20	0 1 2 3	0 1	1 2 3
21	0 1 2 3	0 1	1 2 3
22	0 1 2 3	0 1	1 2 3
23	0 1 2 3	0 1	1 2 3
24	0 1 2 3	0 1	1 2 3
25	0 1 2 3	0 1	1 2 3
26	0 1 2 3	0 1	1 2 3
27	0 1 2 3	0 1	1 2 3
28	0 1 2 3	0 1	1 2 3
29	0 1 2 3	0 1	1 2 3
30	0 1 2 3	0 1	1 2 3

1. Write the key term that best completes each of the following sentences. Refer to the Terms to Know. (Boehm 2003, 30)

Terms to Know

Location	Formal region
Absolute location	Functional region
Hemisphere	Perceptual region
Grid system	Ecosystem
Relative location	Movement
Place	Human-environment interaction
Region	Physical geography
Human geography	Cartography
Meteorology	Geographic Information Systems

Question: Plants and animals depend on one another in a(n) __________.

Answer: *ecosystem*

2. Why do geographers study human systems and human environment relationships? (Boehm 2003, 30)

Answer: *To understand how the earth affects and is affected by human activity so that informed decision can be made*

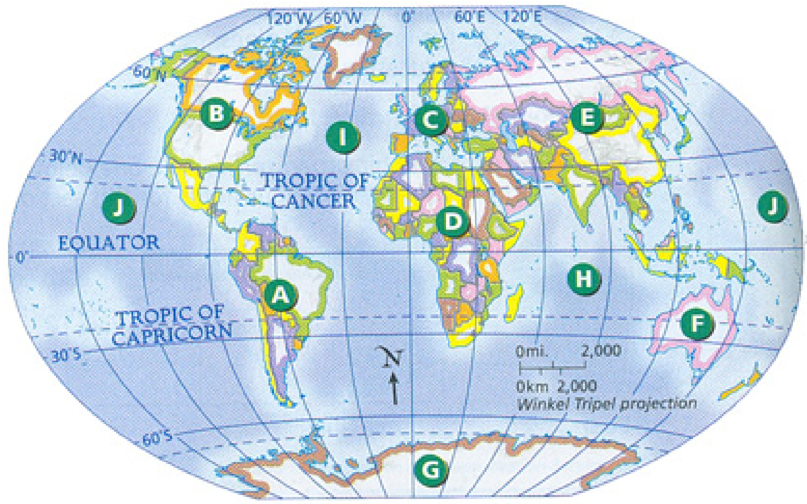
3. Write the key term that best completes each of the following sentences. Refer to the Terms to Know. (Boehm 2003, 30)

Terms to Know	
Location	Formal region
Absolute location	Functional region
Hemisphere	Perceptual region
Grid system	Ecosystem
Relative location	Movement
Place	Human-environment interaction
Region	Physical geography
Human geography	Cartography
Meteorology	Geographic Information Systems

Question: __________ is expressed in relation to other places.

Answer: *Relative location*

4. Match the letters on the map with the places and physical features of the earth. (Boehm 2003, 30)



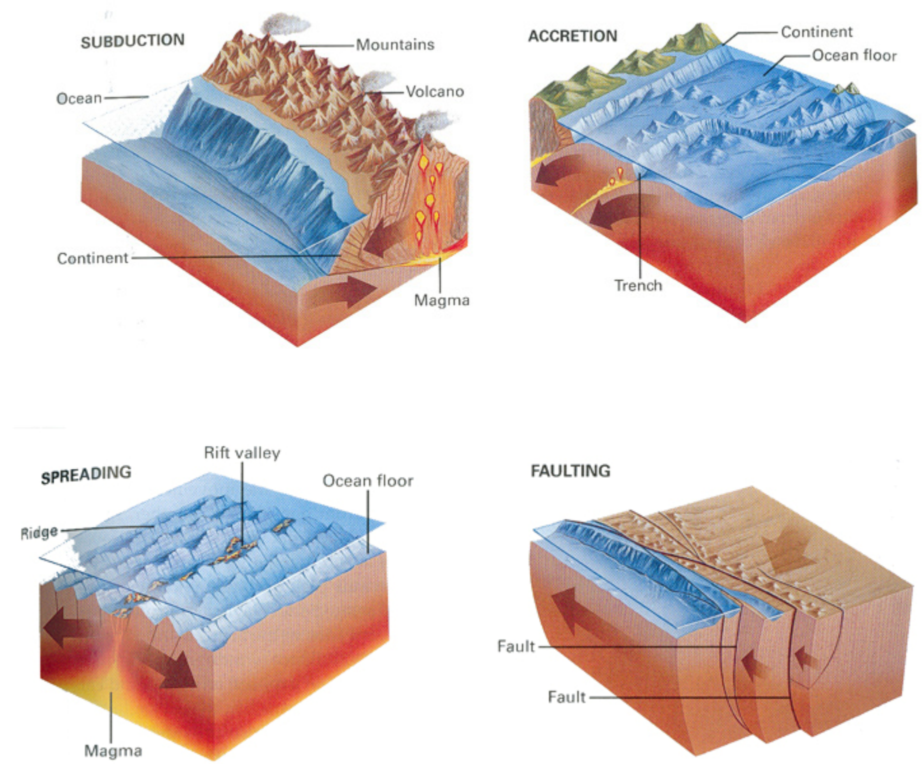
Question: South America

Answer: *A*

5. How do the inner planets differ from the outer planets? (Boehm 2003, 36)

Answer: *Inner planets are smaller and more solid than the larger, gaseous outer planets.*

6. How does the process of accretion create deep trenches in the earth's surface? (Boehm 2003, 41)



Answer: *Trenches are formed during accretion, when a sea plate slides underneath a continental plate.*

7. Define condensation. (Boehm 2003, 49)

Answer: *Condensation is a process that excess water vapor in warm air changes into liquid water when the warm air cools.*

8. Write the key term that best completes each of the following sentences. Refer to the Terms to Know. (Boehm 2003, 52)

<u>Terms to Know</u>

Hydrosphere	Fault
Lithosphere	Weathering
Atmosphere	Erosion
Biosphere	Loess
Continental shelf	Glacier
Mantle	Moraine
Continental drift	Water circle
Magma	Evaporation
Plate tectonics	Condensation
Subduction	Precipitation
Accretion	Desalination
Spreading	Groundwater
Fold	Aquifer

Question: Underwater trenches are created through the process of __________ .

Answer: *accretion*

9. Define Coriolis effect. (Boehm 2003, 64)

Answer: *Coriolis effect is the phenomenon that the global winds are displaced clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere because Earth rotates to the east.*

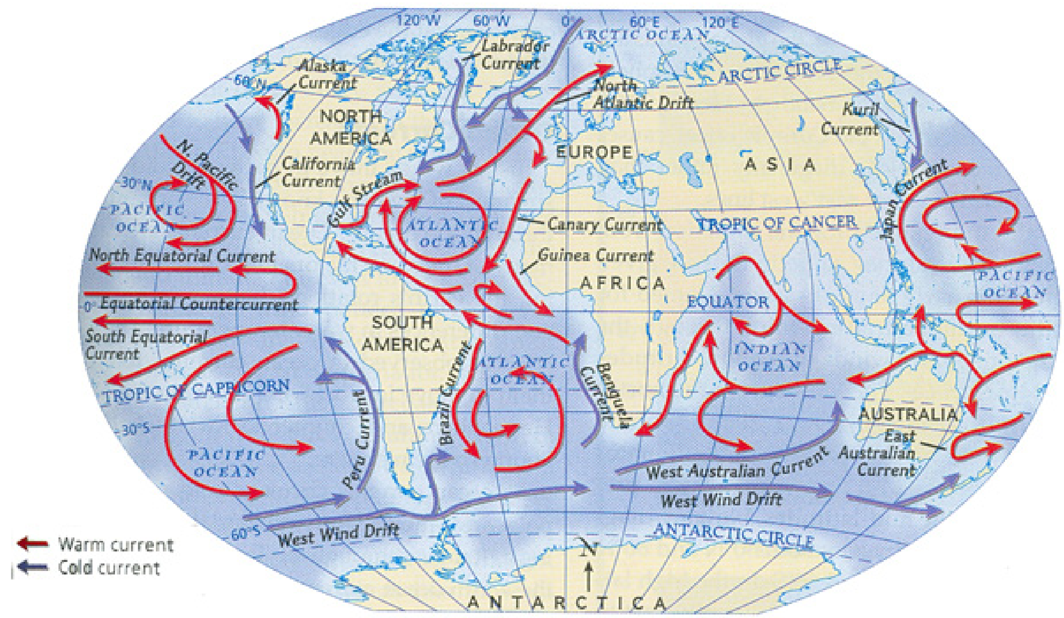
10. Describe the general differences in climate between the low latitudes and the mid-latitudes. (Boehm 2003, 64)

Answer: *Low latitude climates are warm to hot year-round; mid-latitude climates have hot and cold extremes and seasonal changes.*

11. Without Coriolis effect, how might the earth's climate be different? (Boehm 2003, 64)

Answer: *Climates would be more extreme, or not as mild.*

12. Study the map on page 61. If your ship were drifting from west to east in the Equatorial Countercurrent, what might happen as you drifted past longitude 120°W? (Boehm 2003, 64)



Answer: *The ship would reverse its direction and drift from east to west with the North Equatorial Current.*

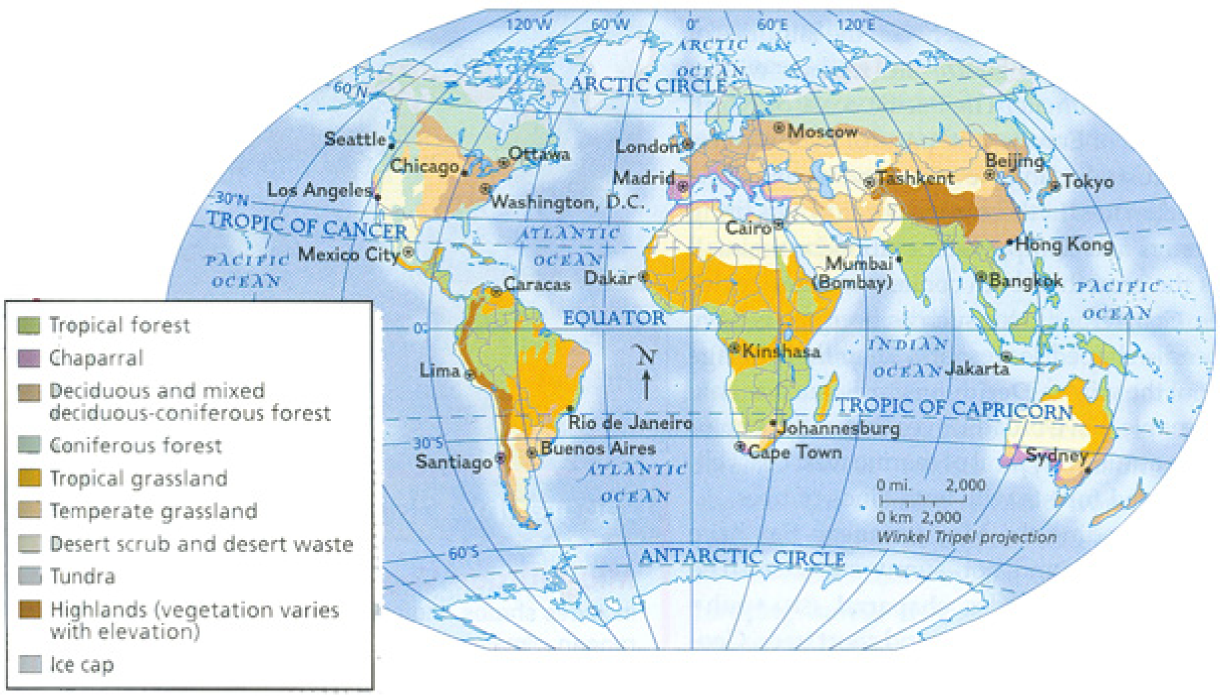
13. Define natural vegetation. (Boehm 2003, 69)

Answer: *Natural vegetation is the plant life that grows in an area where the natural environment is unchanged by human activity.*

14. Define mixed forest. (Boehm 2003, 69)

Answer: *Mixed forest is the forest with both coniferous trees and deciduous trees.*

15. Study the map of world natural vegetation regions on page 67. What vegetation type dominates Europe? Canada and the United States? (Boehm 2003, 69)



Answer:

Europe: deciduous and mixed deciduous-coniferous forests

United States and Canada: deciduous and mixed deciduous-coniferous forests as well as coniferous forests; large area of U.S. temperate grassland

16. On the map of world climate regions on page 66, locate the climate regions for Tashkent, Cape Town, Lima, Chicago, London, and Jakarta. What can you conclude about the relationship between climate and settlement? (Boehm 2003, 69)

Answer:
Dry: Tashkent, Cape Town, Lima
Mid-latitude: Chicago, London
Tropical: Jakarta
Major population centers are found in a variety of climates except high latitude.

17. On a sheet of paper, classify these key terms under the correct heading: earth-sun relationship, climate factors, or climate patterns. (Boehm 2003, 72)

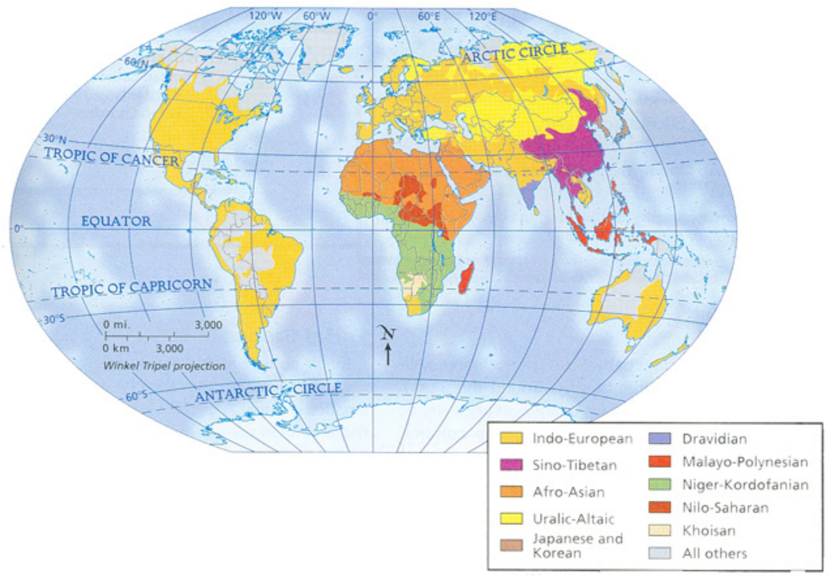
Question: Rain shadow

Answer: *Under climate factors*

18. Define population density. (Boehm 2003, 79)

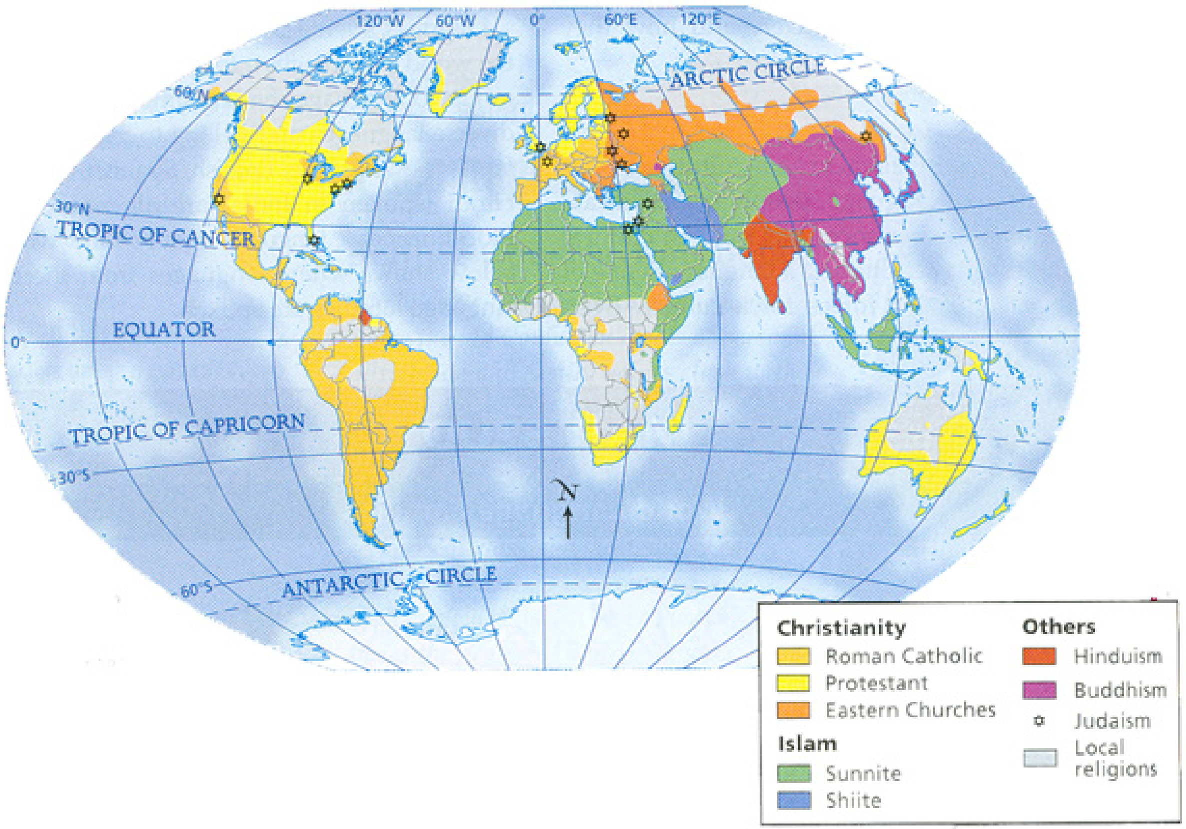
Answer: *Population density is the average number of people living on a square mile or square kilometer of land.*

19. Refer to the language map on page 81. In which three culture regions do languages in the Indo-European family dominate? (Boehm 2003, 83)



Answer: *United States and Canada, Latin America, Europe*

20. Study the map of world religions on page 82. Then write two generalizations about the distribution of the world's religions. (Boehm 2003, 85)



Answer: *Possible answers include that Christianity is practiced throughout North and South America and Europe. Buddhism occurs mainly in East Asia. Islam is practiced mainly in a large area spanning Africa and Asia.*

21. Define natural resource. (Boehm 2003, 95)

Answer: *Natural resource is the elements from the earth that are not made by people but can be used by them for food, fuel, or other necessities.*

22. What might be the advantages and disadvantages to a developing country of joining a free trade agreement? (Boehm 2003, 95)

Answer:
Advantages: increased flow of investment capital into the country, wider markets for exports, jobs
Disadvantages: overdependence on developed countries, environmental damage from uncontrolled industrialization

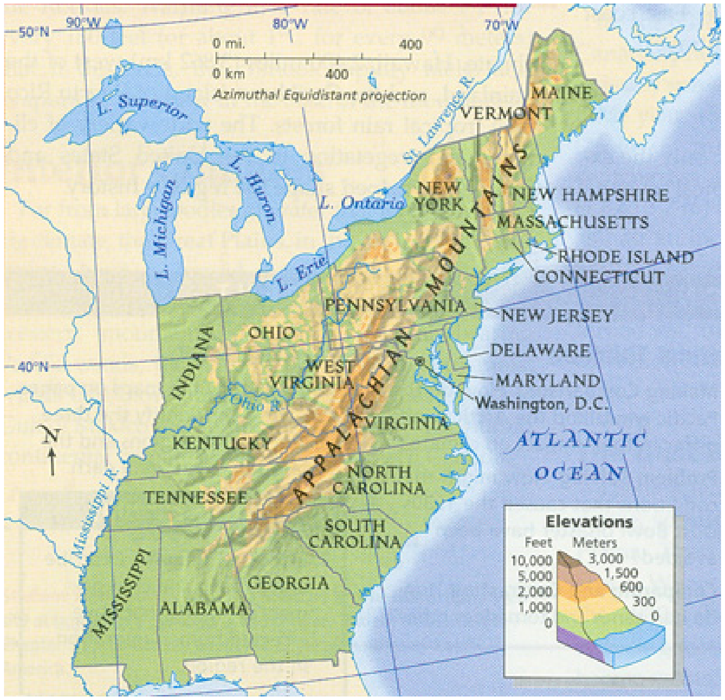
23. Why is the Grand Banks important to Canada? (Boehm 2003, 120)

Answer: *Because it is one of the world's richest fishing grounds.*

24. Write a paragraph describing the effects of a physical process, such as weather or gravity, on the flow of rivers in the United States and Canada. (Boehm 2003, 120)

Answer: *Students might discuss topics such as the fall line, the Continental Divide, Mississippi River floods.*

25. At what elevation is the state of Mississippi? (Boehm 2003, 126)



Answer: *0 to 1,000 feet*

26. Write the key term that best completes each sentence. Refer to the Terms to Know. (Boehm 2003, 128)

<u>Terms to Know</u>

Divide	Chinook
Headwaters	Prairie
Tributary	Supercell
Fall line	Hurricane
Fishery	Blizzard
Timberline	

Question: __________ supply great quantities of fish and other sea animals to North America.

Answer: *Fisheries*

27. Match the letters on the map with the physical features of the United States and Canada. (Boehm 2003, 128)

Question: Great Bear Lake

Answer: *D*

28. What do GPS receivers use to plot exact locations? (Boehm 2003, 152)

Answer: *Satellite signals*

29. On a sheet of paper, write the key term that matches the definition. Refer to the Terms to Know. (Boehm 2003, 154)

<u>Terms to Know</u>

Immigration	Constitution
Native American	Amendment
Sunbelt	Bill of Rights
Urbanization	Cabinet
Metropolitan area	Dominion
Suburb	Parliament
Megalopolis	Bilingual
Mobility	Jazz
Republic	Socioeconomic status
Underground Railroad	Literacy rate
Dry farming	Patriotism

Question: Percentage of people who can read and write

Answer: *Literacy rate*

30. Write the letter of the key term that best matches each definition below. (Boehm 2003, 174)

a. trade surplus	e. trade deficit
b. retooling	f. market economy
c. clear-cutting	g. post-industrial
d. acid rain	h. tariff

Question: Reduced emphasis on heavy industry

Answer: *g*

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