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Naive theories in earth science among Korean students in grades six, eight and ten

Chae, Dong Hyun, Ph.D.
The Ohio State University, 1992
NAIVE THEORIES IN EARTH SCIENCE AMONG KOREAN STUDENTS
IN GRADES SIX, EIGHT AND TEN

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Dong Hyun Chae, B.S., M.S.

* * * *

The Ohio State University
1992

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Adviser
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To my loving wife Keumhee
and my son Yeonwhoong and my daughter Yeonjee
ACKNOWLEDGMENTS

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>VITA</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Rationale</td>
<td>3</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>13</td>
</tr>
<tr>
<td>Purposes of this Study</td>
<td>15</td>
</tr>
<tr>
<td>Research Questions</td>
<td>15</td>
</tr>
<tr>
<td>Importance of this Study</td>
<td>16</td>
</tr>
<tr>
<td>II. LITERATURE REVIEW</td>
<td>18</td>
</tr>
<tr>
<td>Korean Education</td>
<td>18</td>
</tr>
<tr>
<td>The Nature of Naive Theories</td>
<td>21</td>
</tr>
<tr>
<td>Naive Theories in Korean Science</td>
<td>22</td>
</tr>
<tr>
<td>Naive Theories in non-Korean Science</td>
<td>24</td>
</tr>
<tr>
<td>Summary, Pilot Study, and Selected Topics</td>
<td>35</td>
</tr>
<tr>
<td>III. METHODOLOGY</td>
<td>44</td>
</tr>
<tr>
<td>Sample</td>
<td>44</td>
</tr>
<tr>
<td>Instrument</td>
<td>48</td>
</tr>
<tr>
<td>Interview Settings</td>
<td>50</td>
</tr>
<tr>
<td>Data Gathering Procedures</td>
<td>52</td>
</tr>
<tr>
<td>Data Analysis Procedures</td>
<td>54</td>
</tr>
<tr>
<td>IV. RESULTS AND DISCUSSION</td>
<td>58</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Summary of Naive Theory Studies</td>
<td>36</td>
</tr>
<tr>
<td>2. Responses of Four Students in Pilot Study</td>
<td>41</td>
</tr>
<tr>
<td>3. Earth Science Content in Integrated Science, Combined Science, and Separate Earth Science Textbooks</td>
<td>47</td>
</tr>
<tr>
<td>4. Distribution of Subjects</td>
<td>48</td>
</tr>
<tr>
<td>5. Summary of Concepts (Topics) Included in This Study and Questions (Tasks) Related to These Concepts (Topics)</td>
<td>50</td>
</tr>
<tr>
<td>6. Examples of Criteria for Naive Model and Scientific Model</td>
<td>55</td>
</tr>
<tr>
<td>7. Contingency Tables Comparing Models with Each Grade Level for Gravity (I)</td>
<td>62</td>
</tr>
<tr>
<td>8. Contingency Tables Comparing Models with Each Achievement Level for Gravity (I)</td>
<td>64</td>
</tr>
<tr>
<td>9. Percentages of Student Responses to the Question about Gravity (I) by Grade</td>
<td>65</td>
</tr>
<tr>
<td>10. Contingency Tables Comparing Models with Each Grade Level for Gravity (II)</td>
<td>74</td>
</tr>
<tr>
<td>11. Contingency Tables Comparing Models with Each Achievement Level for Gravity (II)</td>
<td>76</td>
</tr>
<tr>
<td>12. Percentages of Student Responses to the Question about Gravity (II) by Grade</td>
<td>77</td>
</tr>
</tbody>
</table>
13. Contingency Tables Comparing Models with Each Grade Level for Day/Night Cycle
14. Contingency Table Comparing Models with Each Achievement Level for the Day/Night Cycle
15. Percentages of Student Responses to the Question about the Day/Night Cycle by Grade
16. Contingency Tables Comparing Models with Each Grade Level for the Phases of the Moon
17. Contingency Tables Comparing Models with Each Achievement Level for the Phases of the Moon
18. Percentages of Student Responses to the Question about the Phases of the Moon by Grade
19. Contingency Tables Comparing Models with Each Grade Level for the Change in Seasons
20. Contingency Table Comparing Models with Each Achievement Level for the Change in Seasons
21. Percentages of Student Responses to the Question about the Change in Seasons by Grade
22. Summary of Grade Level and Achievement Level Differences by Model
23. Comparison of Korean Students' Naive Models to Western Students' Naive Models
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Comparison of the Percentage of Responses to the Question on Gravity (I) for Each Grade Level According to Models</td>
<td>61</td>
</tr>
<tr>
<td>2.</td>
<td>Comparison of the Percentage of Responses to the Question on Gravity (I) for Each Achievement Level According to Models</td>
<td>63</td>
</tr>
<tr>
<td>3.</td>
<td>Comparison of the Percentage of Responses to the Question on Gravity (II) for Each Grade Level According to Models</td>
<td>73</td>
</tr>
<tr>
<td>4.</td>
<td>Comparison of the Percentage of Responses to the Question on Gravity (II) for Each Achievement Level According to Models</td>
<td>75</td>
</tr>
<tr>
<td>5.</td>
<td>Comparison of the Percentage of Responses to the Question on the Day/Night Cycle for Each Grade Level According to Models</td>
<td>85</td>
</tr>
<tr>
<td>6.</td>
<td>Comparison of the Percentage of Responses to the Question on the Day/Night Cycle for Each Achievement Level According to Models</td>
<td>87</td>
</tr>
<tr>
<td>7.</td>
<td>Comparison of the Percentage of Responses to the Question on the Phases of the Moon for Each Grade Level According to Models</td>
<td>93</td>
</tr>
<tr>
<td>8.</td>
<td>Comparison of the Percentage of Responses to the Question on the Phases of the Moon for Each Achievement Level According to Models</td>
<td>95</td>
</tr>
</tbody>
</table>
9. Comparison of the Percentage of Responses to the Question on the Change in Seasons for Each Grade Level According to Models .......................................................................................................................... 107

10. Comparison of the Percentage of Responses to the Question on the Change in Seasons for Each Achievement Level According to Models .............................................................................................................. 109
CHAPTER I
INTRODUCTION

1. 1 Introduction

A filmmaker carried a camera into the crowd of gowned graduates at the 1987 commencement of Harvard University and asked a simple question to twenty five students chosen at random: "Why is it hotter in summer than in winter?" All of the answers except two were that the Earth is closer to the Sun in summer, so it is hotter in summer, but the Earth is farther from the Sun in winter, so it is cooler in winter. This is a good example of the persistence of naive theories about natural phenomena.

Naive theories have been extensively studied. The topics investigated include the Earth as a cosmic body (Nussbaum & Novak, 1976), the changes of state of water (Cosgrove & Osborne, 1983), gravity and the motion of planets (Treagust & Smith, 1989; Vosniadou, 1989), phase changes (Bar & Travis, 1991), photosynthesis (Wandersee, 1985), natural selection (Brumby, 1979), plants and animals (Bell, 1981; Trowbridge & Mintzes, 1985), force (Viennot, 1979), vector concepts (Aguirre & Erickson, 1984), friction and Newton's laws (Chee, 1989), light and color (Anderson & Smith, 1986), particulate nature of matter (Novick & Nussbaum, 1981), and heat transfer and temperature (Tilgner, 1990).
Naive theories seem to persist even when students are exposed to traditional instructional methods (Champagne & Klopfer, 1983). Bodner (1986) suggested that knowledge previously acquired through everyday experience has serious implications for science learning because this knowledge is deeply rooted in the learner's direct experience. Science educators in Korea have also paid attention to students' naive theories. The topics include: photosynthesis (Cho, 1988); changes of state of water (Kook, 1988); Newton's third law (Oh & Kwon, 1988); and mechanics (Jeong, 1989). Yet no one has investigated Korean students' naive theories on earth science topics such as gravity, the day/night cycle, the phases of the Moon, and the change in seasons.

This study is a part of a long-term research agenda which includes: 1) the documentation of the occurrence and the description of naive theories in Korean students; 2) the characterization of these naive theories, recognition of potential sources of these naive theories, and the generation of instructional and curricular strategies for moving those with naive theories toward scientific theories; and 3) research to study the implementation and effects of these new strategies.

This study explores the existence and persistence of naive theories in earth science held by Korean students and investigates the source of Korean students' naive theories. It is designed to characterize these naive theories and provides examples of curricular and instructional modification. It also compares student
responses to open-ended written questions with responses in interview settings.

1. 2 Rationale

1.2.1 Nature of the Learner

A conference of 45 leaders in science education, which was convened in January, 1986 at the University of California, Berkeley with support from the National Science Foundation, forged new understanding of the directions in which science education research is moving. One theme emerging from this research is the need to understand the nature of the learner (Linn, 1987).

Consideration of the learner has been heavily influenced by Ausubel. According to Ausubel (1968), "If I had to reduce all of educational psychology to just one principle I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (p. iv). This means that the learner may come to a learning situation with an understanding of the world phenomena to be studied which is often different from the scientific explanation. Thus, it is important to identify precisely what the learner already knows.

1. 2. 2 Constructivist Perspective of Learning Theory

There have been two points of view with respect to learning theories in science education since the early part of the twentieth century. They come from the behaviorists and the cognitive psychologists.
Behaviorists, who were most influential during the first half of the twentieth century, consider the learner as a black box and focus their research efforts on relationships between stimulus, response, reward, and reinforcement. Researchers working from the behaviorist perspective often investigate methods for fostering student understanding without considering the individual characteristics of subjects.

Cognitive psychologists, on the other hand, place more importance on cognitive processes and the characteristics of the learner. Constructivism, which has become influential, asserts that knowledge is constructed in the mind of the learner on the basis of pre-existing cognitive structures or schemes. Bodner (1986) asserts that constructivism originates from Piaget's work, stating that Piaget believed that knowledge is constructed as the result of a life-long constructive process in light of existing schemes of thought. Constructivism is based upon the Piagetian model including the constructs of assimilation, accommodation, and equilibration. Assimilation involves applying a preexisting scheme to deal with new phenomena. Accommodation involves modifying an existing scheme to fit new situations. Equilibration is the process of restoring balance between present understanding and new experiences.

A constructivist view of learning is analogous to helping a student find the right "fit" for himself or herself between knowledge and reality. Constructivists' views conflict with traditional behaviorists' views, who seek to "match" knowledge with students
(Bodner, 1986). According to constructivists, students' naive concepts and prior learning strongly influence the construction of knowledge so as to "fit" what they perceive of the world, in the same way that many keys may be available to open the same lock.

The present study is based on a constructivist view of learning theory to amass evidence related to student conceptions.

1. 2. 3 Importance of Earth Science in Korea

Earth science in Korea is taught in the elementary, junior high, and senior high school science curriculum. The Korean educational system is organized into a 6-3-3-4 ladder-type school year pattern, which means six years of elementary school, three years of junior high school, three years of senior high school, and four years of college (Ministry of Education, 1988a). In the elementary school, earth science is taught as an integrated science and in the junior high school as a combined science with chemistry and physics. In the senior high school, earth science (I and II) is taught as a separate subject as well as chemistry (I and II), biology (I and II), and physics (I and II). The Roman numeral (I) indicates a basic level course and (II) indicates a more advanced level. Students in humanities, social science tracks, and in the general science track are required to take one basic level (I) course in each of the four science subjects. Students majoring in the science track are required to complete both the basic (I) and advanced (II) level courses from each of the four sciences.
In the United States, earth science is taught as an integrated science in the elementary school just as it is in Korea. At the eighth or ninth grade level of the middle school or junior high school, earth science is taught as a separate subject. At the senior high school level, less than three percent of the senior high school students in the United States have the opportunity to take an earth science as a separate course (Weiss, 1987).

Compared to the United States, earth science in Korea receives much greater emphasis and time in the school science curricula. In light of the importance of earth science in Korea, it is important to investigate naive theories among Korean students.

1. 2. 4 Origins of Naive Theories

Studies in science education have identified a number of factors as potential sources of naive theories. For instance, Champagne and Klopfer (1983) suggest that one source of naive theories is the persistence of conceptions about natural phenomena formed through everyday experiences. Helm (1980) and Ivowi (1984) include everyday experience of the natural world, ineffective teaching, poorly constructed textbooks, and common language usage as contributors to the reinforcement of naive theories. Arons (1981) credits lack of logical reasoning ability as a factor and Ivowi and Oludotun (1987) suggest everyday experience, teachers, instructional television/general television programs, peers, textbooks, and other books as sources contributing to naive theories.

Naive theories about the natural world seem to be highly
resistant to change or alteration (Champagne & Klopfer, 1983). The naive theories held by students and the sources of these naive theories need to be identified so that instructional strategies and materials can be developed to minimize their effects on science learning.

1.2. 5 Scientific Literacy

There is a growing consensus that scientific literacy is an important component of economic growth and of effective citizenship in an industrialized country.

Some researchers point out that the average American is scientifically illiterate. Jon Miller (National Science Board, 1989) found that 63% of American adults believe that dinosaurs coexisted with early humans. Another 65% were confused as to the cause of day and night. Hurd (1969) also claims that the average American is scientifically and technologically illiterate.

The development of scientific literacy is being promoted by two major science curriculum projects - Project 2061 of the American Association for the Advancement of Science, and the Scope, Sequence, and Coordination Project of the National Science Teachers Association. Project 2061, named for the next return of Halley’s Comet, is characterized as establishing scientific literacy for all (AAAS, 1989). NSTA's Project (1989) assumes that science is needed by everyone and that everyone is capable of learning and enjoying science. Linn (1987) asserts that to extend scientific literacy to all citizens, research must focus on effective,
responsive science teaching and an effective, responsive research enterprise for science education. This study is to identify what Korean students know and believe about natural phenomena in earth science in terms of scientific literacy.

1.2.6 Naive Theories

Since the 1950s many studies have investigated misconceptions, which are a kind of naive theory, resulting in a variety of new terms. The problem of selecting the most meaningful and useful terms to describe misconceptions remains unresolved even after international conferences that have focused upon misconceptions in science and mathematics (Abimbola, 1988). Abimbola (1988) proposes that the different terminologies for naive theories come from epistemological and philosophical positions, including empiricism and post-empiricism. The empiricist view considers that students' naive theories (misconceptions) are inferior to an expert's concepts and are wrong. Empiricists prefer terminology such as: "erroneous concepts" (Matteson & Kambly, 1940); "misconceptions" or "misunderstandings" (Treagust & Smith, 1989). Barrass (1984) uses the terms "mistakes" or "error", "misconceptions" (misleading ideas) or "misunderstandings" (misinterpretations) of facts in textbooks, saying that biologists should be concerned if textbooks contain mistakes (errors), misconceptions, misunderstandings, or misrepresentation of concepts (p. 201).
On the other hand, the post-empiricist, or constructivist view of misconceptions considers students' naive theories as efforts to make sense of the world through students' everyday experiences and perspective. Constructivists use terms such as: "naive theories" (Champagne & Klopfer, 1983); "children's conceptions" (Cosgrove & Osborne, 1983); "prior conceptions" (Posner, Strike, Hewson & Gertzog, 1982); "alternative framework" (Driver & Easley, 1978); "alternative conceptions" (Hewson, 1981); "intuitive ideas" (Kim, 1989); and "children's science" (Gilbert, Osborne, & Fensham, 1982).

In the case of students' conceptions related to natural phenomena, Champagne and Klopfer (1983) prefer to use the term naive theories. In their paper, "Naive Knowledge and Science Learning", Champagne and Klopfer (1983) mention that

One of the most striking developments in understanding science learning had been the discovery of the extent and persistence of the naive conceptions about the natural world students bring with them to the classroom. Further investigation revealed that these students' failures were not due to an absence of theories, but rather to the persistence of naive theories that they brought with them to the science class, theories that stand in marked contrast to what students are expected to learn (p. 1).

This study defines and describes naive theories about natural phenomena in earth science.
1. 2. 7 Relationships between Students' Conceptions, Grade Level, and Achievement Level

A frequently debated issue is whether the possession of naive theories is related to the Piagetian stages of students' logical capabilities and to Achievement Levels. Piaget (1969) divides children's cognitive development into three major stages: preoperational stage (2-7 year olds); concrete operational stage (7-11 year olds); and formal operational stage (11-15 year olds). Head (1986) indicates that a developmental progression in thinking may be anticipated. Students who are in a concrete operational stage in thinking may hold concrete ideas based on everyday experiences and observations. For example, such students may believe that the Sun travels around the Earth. Students who are in a formal operational stage in thinking may hold more abstract ideas. These ideas may be consistent with scientific ideas. Also, students with higher achievement scores at a certain grade level may be more capable of formal, abstract thinking that allows them to comprehend, and therefore they adopt scientific explanations of natural phenomena. On the other hand, Champagne and Klopfer (1983) point out that students' conceptions (naive theories) previously acquired through everyday experiences and observations show remarkable consistency across diverse populations, regardless of age and ability.

Students tend to develop their own conceptions about natural phenomena based on their own direct experience and observations. This nature of the students' conceptions may be categorized based upon different Models related to Vosniadou (1989), who categorizes
the students' conceptions as an Intuitive Model or a Copernican Model. Also, Anderson and Smith (1986) categorize the students' conceptions as naive propositions or scientific propositions.

Subjects in the present study were chosen from 6th-, 8th-, and 10th-grade students. Korean 6th-grade students are 12-13 years old, 8th-grade students are 14-15 years old, and 10th-grade students are 16-17 years old. This study includes only students for the formal operational stage according to Piaget. The use of Piagetian cognitive development levels is limited.

For the purpose of this study, subjects' grade level is important because: 1) differences are expected by grade level in the time spent in science instruction at different levels; 2) differences are expected in depth of content at different grade levels; and 3) differences in the format, quantitative nature, and abstractness of textbooks at each grade level are expected. In addition, achievement level difference between students at each grade level will be studied.

In this study, students' conceptions about earth science phenomena are categorized into three different Models (Scientific Model, Naive Model, and "No" Model). The different Models held by students are investigated in relation to Grade Levels and Achievement Levels in order to explore patterns which may exist corresponding to experience, schooling, and cognitive maturity.
Open-Ended Written Questions and Interviews for Identifying Naive Theories

There has been much research on students' conceptions in science education since 1950. One issue which has emerged from this research concerns methodologies for identifying students' conceptions. Three types of research methods have traditionally been used to identify students' conceptions: 1) interviews (Cosgrove & Osborne, 1983; Nussbaum & Novak, 1976); 2) multiple choice tests (Wandersee, 1985); and 3) open-ended written questions (Bar, 1987; Bar & Travis, 1991).

Interviews have been used in many recent investigations of students' science conceptions. Gunstone, White, and Fensham (1988) point out that if we want to know how learners conceptualize the real world of natural phenomena and to investigate how or why individual learners differ in their ideas about the real world of natural phenomena, we need to use interviews. On the other hand, interviews are very time-consuming and require substantial training, and so it is not easy for teachers to identify every individuals' naive theories within large classroom settings (Treagust, 1987).

Multiple choice tests are easy to score at the beginning or upon completion of a specified science topic, so that any science teacher may easily obtain a measure of students' conceptions. One difficulty is to construct an instrument which will detect the many different conceptions that students have about the natural world. Ridgeway (1988) indicates that students' conceptions vary from student to
student and from year to year. Furthermore, multiple choice tests may be less valid because they may be read and interpreted in unintended ways.

Open-ended written questions can be applied to large classroom settings and elicit the variety of unique responses held by students. Bar (1987) suggests the use of open-ended written questions because of this capability. Bar (1987) conducted research comparing the effectiveness of interviews, multiple choice tests, and open-ended written questions for eliciting students' concepts. Bar (1987) found that open-ended written questions elicit responses similar to those of the interviews, while multiple choice tests show significantly different results. Bar and Travis (1991) investigated the effects of the formats of the testing on student responses. Bar and Travis (1991) confirmed that the open-ended written questions elicit responses similar to those of the interviews, but multiple choice tests elicit the different responses.

This study will compare an open-ended written question format with an interview format.

1. 3 Definition of Terms

The following terms defined here for the purposes of this study.

Combined science: Combined science is a science curriculum which combines earth science, chemistry, and physics and is represented by the science textbook in the junior high schools in Korea.
Constructivism: Constructivism is an epistemological theory that highlights the central role of the learner in the learning process. It is assumed that knowledge is actively constructed in the mind of the learner. Constructivists think that meaningful learning occurs as a result of personal actions on data that are derived from active engagement in activities in which students discuss ideas and problems with their peers, manipulate equipment, work independently, listen to the teacher in whole-class settings, and respond to teacher questions (Driver, 1989; Pines & West, 1986; Tobin & Fraser, 1990).

Integrated science: Integrated science is a science curriculum which integrates earth science, biology, chemistry, and physics and is represented by the science textbook in the elementary schools in Korea.

Misconception: In this study a misconception is defined as a representation of a concept which is conceptually incorrect or deficient.

Naive theories: Naive theories are defined as students' intuitive ideas (thoughts) about natural phenomena (processes) which are used to make sense of everyday experiences and observations.

Naive Model: Naive Model is characterized by student responses that are inconsistent with commonly-held scientific theory.

"No" Model: "No" Model is characterized by questions or situations to which students have no response.
Scientific Model: Scientific Model is characterized by student responses that are consistent with scientific theory.

Separate science: Separate science is a science curriculum which treats science disciplines separately with different textbooks for earth science, biology, chemistry, or physics and is represented by the science textbook in the senior high schools in Korea.

1.4 Purposes of this Study

Working toward the goal of scientific literacy in Korea, this study will focus on identifying what Korean students know and believe about selected natural phenomena in earth science. The purposes of this study are: 1) to determine differences in Korean students' conceptions about selected natural phenomena in earth science in relation to Grade Level; 2) to identify how Korean students' conceptions about selected natural phenomena in earth science are related to Achievement Level; 3) to identify and describe naive theories that Korean 6th-, 8th-, and 10th-grade students hold about selected natural phenomena in earth science; 4) to explore the sources of naive theories about selected natural phenomena in earth science as perceived by the students; and 5) to compare student responses to an open-ended written question format and an interview format.

1.5 Research Questions

The research questions of this study are as follows: 1) How are Korean 6th-, 8th-, and 10th-grade students' conceptions about
selected natural phenomena in earth science distributed across the Scientific, Naive, and "No" Model categories?; 2) How are Korean high, average, and low achievement students' conceptions about selected natural phenomena in earth science distributed across the Scientific, Naive, and "No" Model categories?; 3) What are Korean 6th-, 8th-, and 10th-grade students' naive theories about selected natural phenomena in earth science?; 4) To what sources do Korean students attribute naive theories (Models) about selected natural phenomena in earth science?; 5) How do student responses to the open-ended written question format (INTTES) compare to the responses to an interview format for identifying students' naive theories?

1. Importance of this Study

Students develop a world view about natural phenomena through everyday experiences and observations. This is consistent with constructivism. In the constructivist view, knowledge is constructed in the mind of the learner; that is, the learner attempts to make sense of his/her world using knowledge previously acquired through everyday experiences and observations (Treagust & Smith, 1989).

All persons, young and old, are surrounded by the Earth. The Earth consists of the natural phenomena of rocks, rivers, animals, plants, and solar systems including planets. Therefore all persons are potentially Earth scientists. Meyer (1987) points out that people have their own ideas about the Earth, Sun, Moon, rivers, rain, and
other earth science concepts whether they have been formally taught or not. Meyer suggests that many students may bring diverse naive theories concerning natural phenomena in earth science into the classroom.

Champagne and Klopfer (1983) point out that naive theories previously acquired through everyday experiences and observations show remarkable consistency across diverse populations, irrespective of age and ability. Recently, as the development of technology has progressed, the field of science has become conceptually more complex and this complexity influences the content of students' science knowledge. Furthermore, many recent studies have explored naive theories about natural phenomena held by students in the United States, Australia, and some European countries (Pfundt & Duit, 1987). However, only a few studies have investigated students' naive theories in Korea (Cho, 1988; Jeong, 1989; Kook, 1988; Oh & Kwon, 1988).

This study will provide information about the nature and sources of Korean students' naive theories in earth science. This information may be a valuable resource for teachers, textbook publishers, and curriculum developers. Osborne, Bell, and Gilbert (1983) point out that teachers, curriculum developers, and textbook publishers need to identify students' naive theories, and to incorporate instructional strategies and learning activities designed to move students' understanding toward appropriate Scientific Models.
CHAPTER II
LITERATURE REVIEW

This chapter presents a review of literature relevant to the present study. It is divided into five sections: 1) Korean education; 2) the nature of naive theories; 3) naive theories in Korean science; 4) naive theories in Non-Korean science; and 5) summary, pilot study, and selected topics.

2.1 Korean Education

Korea (South Korea), with a population of 45 million, is located at the northeastern corner of Asia. Korea is a country with one of the longest histories in the world (over 5,000 years recorded history).

The first modern style school in Korea was established at the end of the nineteenth century when the royal court of the Chosun (old Korea) dynasty decided to adopt its open door policy. However, the forced annexation of Korea by Japan in 1910 resulted in colonizing Korean education by promulgating the Chosun Education Decree and the Private School Decree. Since 1945, Korea's liberation from Japanese colonial rule marked a new era in the development of Korean education. The organization of the educational system is 6-3-3-4. That is, six years of elementary level, three years of junior high level, three years of senior high level, and four years of college level (Ministry of Education, 1988a).
Elementary education is compulsory and free for every child in Korea. The money for the elementary schools comes from taxes and the government requires children to go to school until they are thirteen years old. After graduation from elementary school, children are distributed to junior high schools by a lottery system. Cost-free education is extended to only a few junior high schools in rural areas. In spite of this, 98.7% of the elementary level graduates advance to the junior high school (Ministry of Education, 1988a). After graduation from junior high school, the students are distributed to state-run senior high schools or private senior high schools by unified entrance examination results. There are three types of senior high schools: general senior high schools; vocational senior high schools; and other specialized senior high schools (e.g., arts education, physical education, and science education). Ninety-one percent of the junior high school graduates advance to senior high school (Ministry of Education, 1988a).

After completing the three years of the senior high school, students can start their higher education in a two-year college, a four-year college (university), or a specialized professional college. Most colleges admit students based on entrance examination records. Admission to college (university) is very competitive. Only about 30-40% of the applicants are accepted. Many students who do not qualify for college (university) in a given year, will repeatedly try to gain admission, and so admission to college (university) becomes more competitive each year.
Science in Korea is considered one of the most important subjects, along with the native language and mathematics. In the elementary school, the science curriculum includes biology, chemistry, earth science, and physics as "integrated science", taught 2-4 hours a week. In the junior high school, students study biological science and combined science which integrates chemistry, earth science, and physics. Science is taught 3-4 hours a week. In the senior high school, the science curriculum consists of four separate subjects (biology, chemistry, earth science, and physics), which have two levels each (e.g., earth science I and earth science II). The Roman numeral (I) implies the basic level and the numeral (II) stands for the more advanced level. All Korean senior high school students are required to take the basic level (I) sciences. Science track students are required to take basic (I) and advanced level sciences (II). Science is taught 4-8 hours a week, depending upon whether the student is in the general track or the science track.

Koreans are proud of having one of the lowest illiteracy rates in the world. Only 2-3% of the general population cannot read or write the native language. Since the 1980s, Korea has been considered one of the most rapidly progressing economies in the world. By a general consensus, Korean education has played a important role in Korea's low illiteracy rate and fast economic growth by providing the various types of educated manpower needed by rapidly growing industries.
On the other hand, much concern has arisen about Korean (science) education. The international assessment, *Science Achievement in Seventeen Countries* (International Association for the Evaluation of Educational Achievement, 1988), supports these concerns. Korean 10-year-olds ranked first along with the Japanese out of 15 countries, while Korean 14-year-olds ranked seventh out of 17 countries, and Korean 17-year-olds ranked at the bottom of 17 countries. The recent international assessment, *International Assessment of Educational Progress*, 1992, shows that Korean 13-year-olds still ranked first out of 15 countries. Han (1984) indicates that the Korean science curriculum content is very abstract, broad, and difficult for students to understand. Han also points out that the curriculum does not include everyday applications of science in society and in technology. Another possible reason for the students' poor performance may be due to naive theories that students hold. This leads the researcher to explore the existence and persistence of naive theories in earth science held by Korean students, and to investigate the source of Korean students' naive theories. This also leads to a need to describe the nature of naive theories as reported in the literature.

2. 2 The Nature of Naive Theories

The investigation of students' naive theories has been an important focus of science education research since 1980. A set of general findings on the nature of naive theories has emerged from some research studies (Champagne & Klopfer, 1983; Osborne &
Most naive theories have the following characteristics: 1) all persons, young or old, may hold naive theories concerning scientific phenomena before they experience the formal study of science; 2) naive theories show remarkable consistency across diverse populations regardless of age, ability or nationality; 3) naive theories are remarkably resistant to change by exposure to traditional instruction; 4) naive theories are often significantly different from the views of scientists; and 5) naive theories are sensible and coherent from the student's point of view, and so naive theories may be influenced in unanticipated ways by science instruction.

In light of the nature of the naive theories, science educators in Korea have paid close attention to students' naive theories. These studies are examined in the next section.

2.3 Naive Theories in Korean Science

There have been four studies of naive theories in Korea which have focused upon the following: photosynthesis; the change of state of water; Newton's third law; and elementary mechanics.

Cho (1988) studied Korean 5th-and 8th-grade students' misconceptions about photosynthesis using a multiple choice test and interviews. Cho also investigated the relationship of misconceptions to logical ability. Cho used three instruments for his study: the Photosynthesis Concepts Test, the Piagetian Logical Reasoning Test, and a questionnaire to collect information about background variables. The subjects were 201 fifth-grade students
and 239 eighth-grade students. Regression analysis indicated that prior knowledge and logical reasoning were the best predictors of achievement on the photosynthesis test. These variables accounted for 22% of the variance at the fifth grade level and 40% of the variance at the eighth grade level. Students had misconceptions about how plants make food, the definition of food, how plants use light, the function of roots and leaves, and photosynthesis products. The number of misconceptions declined from the fifth to the eighth grade.

Kook (1988) investigated Korean students' conceptions about ice melting and water boiling, condensing, and evaporating using a modified questionnaire-about-events method. Fifty-one Korean students were randomly selected from seventh grade to eleventh grade. The results were that: 1) some student conceptions are superficial and nonscientific; 2) some nonscientific terminology was more frequently used by older students than younger students; and 3) the older students had fewer misconceptions.

Oh and Kwon (1988) identified the sources of Korean students' misconceptions about Newton's third law using a multiple choice test. The subjects were 219 eighth-grade student, 223 eleventh-grade students, and 153 college students. The results showed that students' conceptions were significantly affected by: 1) the size of objects involved, existence of physical contact, and kinds of objects; 2) the source of attraction; and 3) the magnitude of potential force, state of motion, velocity, weight, friction, and acceleration.
Jeong (1989) investigated pre-instructional, conceptual frameworks in elementary mechanics using open-ended written questions. The subjects were 135 female, eleventh-grade Korean students; 124 male, tenth-grade Korean students; and 51 Korean college freshmen students. The results showed that pre-instructional conceptual frameworks are very persistent across all groups of subjects and the pre-instructional conceptual frameworks on elementary mechanics are systematically categorized by response types.

It seems that limited research has been done on naive theories in the field of science in Korea compared to studies done in other countries: one study in the field of earth science; one study in biology; and two studies in physics. Most Korean studies have investigated the naive theories of studies in junior and senior high school. Only Cho (1988) investigated Korean elementary students' naive theories.

2. 4 Naive Theories in Non-Korean Science

Many recent studies have explored naive theories of natural phenomena held by students in the United States, Australia, Nepal, and some European countries. Four studies in biology, three studies in chemistry, five studies in physics, and nine studies in earth science, will be discussed.
2. 4. 1 Biology

Naive theories in biology which have been studied include those related to photosynthesis, natural selection, and concepts of plants and animals.

A study of students' concepts of natural selection was conducted by Brumby (1979) using a multiple choice test. Sixty-three first year students from five science departments of two universities and one college were selected. A significant portion of students held Lamark's theory that organisms can gradually adapt to a change in the environment and evolve.

Bell (1981) studied children's ideas about plants using interviews. The subjects were 29 children in the age range 6-17 years. Bell found that some students interviewed did not consider grass, oak trees, or carrots to be plants. A study of students' alternative conceptions of animals and animal classification was conducted by Trowbridge and Mintzes (1985) using interviews. The subjects were 62 students from the fifth grade, junior high, and college. The result showed that some students of all ages hold a highly restricted conception of the term "animal" limiting their definition to four-legged, land mammals.

Wandersee (1985) used a multiple choice test to investigate the relationship between student understanding of concepts of photosynthesis and the historical development of the concept. The subjects were 420 fifth-grade students, 393 eighth-grade students, 383 eleventh-grade students, and 209 college students. The results show that students at all grade levels hold misconceptions on
photosynthesis which are similar to those that are documented in the history of science such as Aristotle's photosynthesis, and that elementary and junior high school students are more likely to hold concepts which were previously accepted by "scientists" but which now have been discarded or modified.

Most studies of biology naive theories have conducted using multiple choice tests except one study (Bell, 1981). These studies have investigated across grade levels from elementary students to college students.

2. 4. 2 Chemistry

Naive theories in chemistry which have been studied include elementary school, junior high school, senior high school, and college level students' understanding of the particulate nature of matter, and college level pre-service science teachers' conceptions of heat transfer and temperature.

A study of pupils' understanding of the particulate nature of matter was conducted by Novick and Nussbaum (1981) using a multiple choice test. The subjects included 83 elementary school students, 339 junior high school students, 88 senior high school students, and 66 university sophomore students. The results showed that among students at the university and high school, fifty percent did not attribute the uniformity of particle distribution in gases to inherent particle motion, and sixty percent of students did not picture space in a gaseous medium.
A study of college students' views of the particulate nature of matter was conducted by Gabel, Samuel, and Hunn (1987) using a multiple choice item (a 14 item Nature of Matter Inventory). The subjects were 90 students enrolled in a basic science skills course at Indiana University. The students' views of the particulate nature of matter were frequently distorted. The results were:

1. Students believed that atoms enlarged when atoms changed from liquids to gases.
2. Students believed that gases were in orderly forms.

Tilgner (1990) investigated college level pre-service science teachers' conceptions of heat transfer and temperature using interviews. Six pre-service science teachers were interviewed. Tilgner found that the pre-service science teachers hold the caloric conceptual model of heat transfer and temperature rather than modern thermodynamics concepts.

Most studies of chemistry naive theories have conducted using multiple choice tests and interviews. Subjects are college level students except one study (Novick & Nussbaum, 1981).

2. 4. 3 Physics

Naive theories in physics which have been studied include force, vector concepts, light and color, friction, and Newton's laws.

Viennot (1979) conducted an important study about force using a multiple choice test. The subjects were several hundred students, mostly French, British, and Belgian, ranging from the last year at
high school to the third year at the university. Viennot found the following:

1. Students hold a surprising number of wrong ideas, regardless of age and nationality.
2. Students believe that constant motion requires a constant force.
3. Students believe that when a body is moving, there is a force acting on it in the direction of movement.

Aguirre and Erickson (1984) conducted a study of three vector concepts (position, displacement, and velocity) using interviews. The subjects were 20 tenth-grade students selected from a group of volunteers from two different schools in a large suburban school district in British Columbia. Eighty percent of the students believed that the magnitude of the velocity contributed by the boat's motor is changed in some way by the interaction with the current.

A study of children's conceptions of light and color was conducted over a two-year period by Anderson and Smith (1986) using open-ended written questions and interviews. The subjects were 125 fifth grade students. The results were:

1. Forty-one percent of students believed that light brightens or illuminates objects rather than bounces or reflects off of objects.
2. Forty-eight percent of students believed that white light is clear or colorless rather than a mixture of colors.

Chee (1989) used a multiple choice test to investigate students' misconceptions concerning Newton's laws, frictional
force, and work. The subjects were 148 high school students. Chee found the following misconceptions:

1. When an object remains at rest, there is no frictional force operating regardless of whether there is any applied force acting on it.
2. Students misunderstood Newton's laws. They didn't realize that action and reaction are acting on the same body.
3. In circular motion, students find it difficult to visualize the exerted force towards the center perpendicular to instantaneous displacement of the object along the tangent direction.

Park (1990) investigated college students' misconceptions about mechanics using interviews in a study of variables related to selection of mental representation and problem solving strategy during mechanics problem solving. The subjects were four college students. The results indicated that students held misconceptions about different force pairs, residual force on moving bodies, and acceleration.

Most studies of physics naive theories have been conducted using diverse methodologies (multiple choice tests, open-ended written questions, and interviews). These studies have investigated across countries (U. S. A., French, British, Belgian, and Canada), ranging from 5th-grade students to college students. Studies on naive theories in earth science will be discussed in the next section.
2. 4. 4 Earth Science

Naive theories in earth science which have been studied include the size, shape, and motion of the Earth and the Sun; gravity; the change of the state of water; the motion of planets; the day/night cycle; the phases of the Moon; the change in seasons; earthquakes; and intuitive ideas about water in the atmosphere.

Nussbaum and Novak (1976) studied children’s concepts of the Earth using interview techniques. Twenty-six children were selected from two 2nd-grade classes. Five different notions were identified:

1. Three students believed that the Earth is flat and not round like a ball.
2. Seven students believed that the Earth is round like a ball, but lacked knowledge of the unlimited space that surrounds the Earth.
3. Three students had some idea of the unlimited space that surrounds the Earth but did not think of the Earth as a frame of reference for up-down directions.
4. Seven students believed that the Earth is a spherical planet, thought of the Earth as a frame of reference for up-down directions, and related to the Earth as a whole, but did not relate up-down directions to the Earth’s center.
5. Six students believed that the Earth is a spherical planet, surrounded by space, and that objects fall to the center.

Mali and Howe (1979) studied the development of Earth and gravity concepts, and investigated cognitive/conceptual
development among Nepali children using structured interviews. A series of Piagetian tasks of conservation, seriation, and classification were administered to the Nepali children by trained workers. Two hundred and fifty children (ages 8, 10, and 12) were used for this study. They found the following:

1. The notions about Earth held by Nepali children are similar to the notions held by Americans and Israeli children. They believe that the Earth is flat.
2. The frequency of higher level notions increases with age.
3. A concrete operational level of logical thinking appears to be necessary for the development of higher level notions of the Earth.
4. Development of higher-level notions of the Earth appears to correlate with both the level of cognitive development and schooling.

Klein (1982) conducted a cross-cultural research study about children's concepts of the Earth and Sun using interviews. The study involved twelve Mexican-American and twelve Anglo-American children. Klein found that there was no apparent difference in the number of concepts understood or in the explanations and answers given by Mexican-American and Anglo-American children.

Children's conceptions of the changes of state of water were studied by Cosgrove and Osborne (1983) using an audio-taped clinical interview technique. Forty-three school children ranging in age from 8-17 years were interviewed. Children were randomly selected from a range of classrooms with average to slightly above
average scholastic ability. Subjects were asked questions about ice melting and water boiling, condensing, and evaporating. Cosgrove and Osborne concluded that:

1. Children's understanding of scientific terms was frequently superficial despite the fact that children could associate the correct technical term with an event.
2. Children of all ages held common naive views about observed phenomena.
3. The popularity of certain views changed with the age of pupils. However, some nonscientific views were more popular with older children than with younger children. For example, more 15-year-olds than 12-year-olds considered that water changed into hydrogen and oxygen.
4. Scientific Models which students have been taught appear to be very abstract and poorly understood.

Treagust and Smith (1989) studied students' understanding of gravity and the motion of planets using interviews and a two-tier multiple choice test. The interviews were given to 24 tenth-grade students and the diagnostic pencil-and-paper test was given to 113 tenth-grade students in Australian schools. Treagust and Smith found the following misconceptions or misunderstandings:

1. A planet's gravity is related to its distance from the Sun.
2. The Sun's gravity influences not only the planets' orbit around the Sun but also the gravity of the planet.
3. The planet's rotation affects its gravity.
4. The rotation of a planet depends on its density.
5. The surface temperature of a planet affects its gravity.

Vosniadou (1989) conducted a study of American children's knowledge of observational astronomy to demonstrate the kinds of Intuitive Models that children hold and to show how these Models influence the acquisition of science knowledge. The subjects were 60 children ages 6, 9, and 12 coming from middle-class families and attending the same school in a small midwestern town. A questionnaire (open-ended written questions) was used to investigate children's knowledge of the size, shape, and motion of the Earth and the Sun, and of the notion of gravity. The results showed:

1. Children form intuitive understandings of the world around them, such as: the Earth is flat and stationary rather than a rotating sphere; things fall in a downward direction rather than toward the center of a rotating sphere; and the Sun and the Moon move in an up/down or east/west direction.

2. Children eventually change their intuitive understanding as they are exposed to the Copernican theory of the solar system.

3. The process of conceptual change is a slow and gradual one.

Vosniadou and Brewer (1989) investigated elementary school children's concepts of the Earth's shape and the related concept of gravity using a questionnaire (open-ended written questions) and interviews. The subjects were 60 children who attended an elementary school in a town in Illinois; 20 first graders, 20 third graders, and 20 fifth graders. The results show that children are quite inconsistent concerning their understanding of the Earth's
shape and related concepts. For example, many children said that the Earth is round but at the same time stated that it has an edge and that people could fall down from that edge. Vosniadou and Brewer suggest that students' inconsistent notions are constructed in an effort to reconcile a naive concept of a flat Earth with information coming from adults that the Earth is a sphere.

Schoon (1989) conducted research about misconceptions in earth science to see how misconceptions varied by grade, gender, and race using a multiple choice test. Subjects were 1,213 students in fifth, eighth, and eleventh-grade and adults in college and trade school. The results indicate that all the students held many misconceptions about earth science, and the number of misconceptions varied by gender, race, and grade level. Generally, females had more misconceptions than males, and 5th-and 8th-grade students had more misconceptions than trade school students. What is more interesting is that having taken an earth science course did not influence the number of misconceptions held.

A study of students' intuitive ideas about water in the atmosphere (seven subconcepts: water vapor, humidity, evaporation, condensation, sublimation (I), sublimation (II), and dew point) was conducted by Kim (1989) using interviews. The subjects were 36 students from the fifth grade, eighth grade, eleventh grade, and college level. Kim categorized the students' answers into a less sophisticated, differentiation (discontinuous) change, and a more sophisticated continuum. The results are:
1. Students hold three to seven different intuitive ideas (notions) for each subconcept.

2. The notions are arranged on a less sophisticated to a more sophisticated continuum.

3. The higher the grade and ability levels, the more sophisticated are the notions.

All studies of earth science naive theories were conducted before 1990 using diverse methodologies (multiple choice tests, open-ended written questions, and interviews). These studies have investigated across grade levels with a greater frequency of study of elementary level students.

2. 5 Summary, Pilot Study, and Selected Topics

2. 5. 1 Summary

Table 1 provides a summary of the research studies on students' naive theories which have been discussed above. For each study, the names of the researchers, date, grade level, topics/concepts, methods, and country are reported. The coding used for the methods is explained at the bottom of Table 1.
Table 1

Summary of Naive Theory Studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Grade Level</th>
<th>Topics/ Concepts</th>
<th>Methods</th>
<th>Countries</th>
<th>Remarks</th>
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<tr>
<td>Nussbaum &amp; Novak (1976)</td>
<td>2nd grade</td>
<td>Earth</td>
<td>I</td>
<td>U. S. A.</td>
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<td>Mali &amp; Howe (1979)</td>
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<td>Earth &amp; Gravity</td>
<td>I</td>
<td>Nepal</td>
<td></td>
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<td>Brumby (1979)</td>
<td>college</td>
<td>natural selection</td>
<td>MCT</td>
<td>U. S. A.</td>
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<tr>
<td>Viennot (1979)</td>
<td>12th, college</td>
<td>force</td>
<td>MCT</td>
<td>French, etc.</td>
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<tr>
<td>Novick &amp; Nussbaum (1981)</td>
<td>elementary, junior &amp; senior high, college</td>
<td>matter</td>
<td>MCT</td>
<td>U. S. A.</td>
<td></td>
</tr>
<tr>
<td>Bell (1981)</td>
<td>1st to 12th</td>
<td>plants</td>
<td>I</td>
<td>New Zealand</td>
<td></td>
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<tr>
<td>Klein (1982)</td>
<td>elementary school</td>
<td>Earth &amp; Sun</td>
<td>I</td>
<td>U. S. A.</td>
<td></td>
</tr>
<tr>
<td>Cosgrove &amp; Osborne (1983)</td>
<td>3rd to 12th</td>
<td>changes of state of water</td>
<td>I</td>
<td>U. S. A.</td>
<td></td>
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<tr>
<td>Aguirre &amp; Erickson (1984)</td>
<td>10th</td>
<td>vector</td>
<td>I</td>
<td>Canada</td>
<td></td>
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<td>Trowbridge &amp; Mintzes (1985)</td>
<td>5th, junior high, college</td>
<td>animal</td>
<td>I</td>
<td>U. S. A.</td>
<td></td>
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<td>Wandersee (1985)</td>
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<td>photosynthesis</td>
<td>MCT</td>
<td>U. S. A.</td>
<td></td>
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<tr>
<td>Anderson &amp; Smith (1986)</td>
<td>5th</td>
<td>light, color</td>
<td>OEWQ/I</td>
<td>U. S. A.</td>
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"Table 1 (continued)"

<table>
<thead>
<tr>
<th>Author(s)</th>
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<th>Topic</th>
<th>Assessment</th>
<th>Location</th>
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<td>Gabel, Samuel, college &amp; Hunn (1987)</td>
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<td>matter</td>
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<td>U. S. A.</td>
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<td>Cho (1988)</td>
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<td>photosynthesis</td>
<td>OEWQ/I</td>
<td>Korea</td>
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<td>Kook (1988)</td>
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<td>water</td>
<td>OEWQ</td>
<td>Korea</td>
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<tr>
<td>Oh &amp; Kwon (1988)</td>
<td>8th, 11th, college</td>
<td>Newton's third law</td>
<td>MCT</td>
<td>Korea</td>
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<td>Jeong (1989)</td>
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<td>Mechanics</td>
<td>OEWQ</td>
<td>Korea</td>
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<td>gravity, motions of planets</td>
<td>OEWQ/I</td>
<td>Australia</td>
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<td>Vosniadou (1989)</td>
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<td>U. S. A.</td>
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<td>Vosniadou &amp; Brewer (1989)</td>
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<td>Earth, gravity</td>
<td>OEWQ/I</td>
<td>U. S. A.</td>
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<td>Schoon (1989)</td>
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<td>day/night cycle, etc</td>
<td>MCT</td>
<td>U. S. A.</td>
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<td>Kim (1989)</td>
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<td>water</td>
<td>I</td>
<td>U. S. A.</td>
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<td>Chee (1989)</td>
<td>high school</td>
<td>Newton's law, frictional force, work</td>
<td>OEWQ</td>
<td>U. S. A?</td>
</tr>
<tr>
<td>Jeong (1989)</td>
<td>10th, 11th, college</td>
<td>mechanics</td>
<td>OEWQ</td>
<td>Korea</td>
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<tr>
<td>Tilgner (1990)</td>
<td>college</td>
<td>heat transfer, temperature</td>
<td>I</td>
<td>U. S. A.</td>
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<tr>
<td>Park (1990)</td>
<td>college</td>
<td>mechanics</td>
<td>I</td>
<td>U. S. A.</td>
</tr>
</tbody>
</table>

OEWQ: open-ended written questions  MCT: multiple choice tests  I: interviews  OEWQ/I: open-ended written questions(multiple choice test) & interviews  *: earth science studies
The present review of literature reveals the following:

1. All the earth science studies (*) were conducted before 1990.

2. Of the earth science studies (*), only three studies have investigated across grade levels (from elementary through senior high) with more studies including a focus upon elementary school age students.

3. Many recent studies do not use a mixed methodology (quantitative and qualitative) for identifying and describing naive theories.

4. Many recent studies have explored naive theories of science natural phenomena held by students in the United States, Australia, and some European countries. However, few studies have investigated students' naive theories in Korea (N=4). None of these studies have investigated naive theories of gravity, the day/night cycle, the phases of the Moon, and the change in seasons.

5. Studies in the U.S.A tend to be more spread across grade levels with a greater frequency of study of elementary, junior high, and senior high school age students than do the Korean studies.

6. Most Korean studies have investigated junior and senior high school students' naive theories except one study (Cho, 1988).

7. The literature review includes four research techniques commonly used for identifying students' naive theories: open-ended written questions; multiple choice tests; interviews;
and mixed methodology (e. g., open-ended written questions and interviews, or multiple choice tests and interviews). The mixed methodology is of special interest since different perspectives can be compared. Patton (1991) points out that triangulation is one way to strengthen the research design of a study.

8. There has been a notable increase in the number of research reports investigating into naive theories with 12 between 1988-1990 while over the preceding 3 years there were only three.

2. 5. 2 Pilot Study

The pilot study was conducted between June 4, 1991 and July 15, 1991 at Columbus, Ohio. Students and their parents were informed about the purpose of this pilot study, and parental permission was obtained. The sample for the pilot study was 4 Korean students: 2 elementary school students in grade 6; 1 junior high school student in grade 8; and 1 senior high school student in grade 10. They were individuals who the researcher knew personally through the Korean community in Columbus, Ohio. Three students (one grade 6, one grade 8, and one grade 10) were Korean students whose fathers were at The Ohio State University for one year as visiting professors. They had been in the United States for 6 months. One student (grade 6) who had been in the United States for 8 months was a Korean whose father was in a doctoral program in the department of physics at The Ohio State University. Students
were in the same grade in schools in the United States as in Korea. These students were chosen so that the pilot study could be conducted in the Korean language.

The INTTES was administered first. After a lapse of one week, each student was interviewed based on a review of that student’s responses to the items on the INTTES.

Table 2 shows the results of the pilot study. The results show that naive theories (Models) about the phases of the Moon and the change in seasons were persistent. For example, in response to "Why is it hot in summer and cold in winter?" two 6th-grade students and one 10th-grade student said "it is hotter in summer because the Earth is closer to the Sun in summer and it is cooler in winter because the Earth is farther from the Sun in winter". One 8th-grade student attributed the temperature differences to the relative length of the day. Since the days are longer in the summer than in winter, the temperature would be hotter in the summer than in the winter.
Table 2

Responses of Four Students in Pilot Study

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<thead>
<tr>
<th>Topics</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#1</td>
</tr>
<tr>
<td>Gravity (I)</td>
<td>*</td>
</tr>
<tr>
<td>Gravity (II)</td>
<td>**</td>
</tr>
<tr>
<td>Day/night cycle</td>
<td>*</td>
</tr>
<tr>
<td>Phases of the Moon</td>
<td>**</td>
</tr>
<tr>
<td>Change in seasons</td>
<td>**</td>
</tr>
<tr>
<td>Grade Level</td>
<td>6</td>
</tr>
</tbody>
</table>

*: Scientific Model  **: Naive Model

Table 2 also indicates that no clear pattern related to grade level could be detected. It is apparent that the phases of the Moon and the change in seasons involved more Naive Models on the part of the subjects than did gravity and the day/night cycle items. Gravity (II) which related gravity to position on the Earth's surface also suggests Naive Model prevalence among some of the younger subjects but not all.

2. 5. 3 Selected Topics

The topics selected from the field of biology, chemistry, earth science, and physics, in non-Korean science as well as Korean science, are natural phenomena about which the student may hold
naive theories. Champagne and Klopfer (1983) prefer to use the term naive theories to describe student conceptions about natural phenomena obtained through everyday experiences and observations. In the present study, the topics investigated are gravity, the day/night cycle, the phases of the Moon, and the change in seasons. These topics are natural phenomena about which students may hold naive theories based upon everyday experiences and observations.

These topics are considered important in the Korean science curricula. They are included in the integrated science textbook in the elementary school (Ministry of Education, 1988b), the combined science textbook in the junior high school (Ministry of Education, 1988c), and the separate earth science textbook in the senior high school (Ministry of Education, 1988d)

This study is essential based on the literature review, and results of the pilot study because:

1. This study identifies and describes naive theories that Korean students hold about natural phenomena in earth science.
2. Due to the repeated incidence of naive theories, the emphasis in Korean science education, and the lack of research with Korean students on these topics the following concepts have been selected; 1) gravity, 2) the day/night cycle, 3) the phases of the Moon, and 4) the change in seasons.
3. This study uses a mixed methodology for identifying and describing naive theories. The open-ended written questions appear more suitable for identifying students' naive theories about natural phenomena in earth science. Also, interviews
are used to validate the open-ended written questions, to investigate students' naive theories which might be overlooked by the open-ended written questions, and to identify the sources of naive theories.

4. This study utilizes elementary school students (sixth grade), junior high school students (eighth grade), and senior high school students (tenth grade).
CHAPTER III
METHODOLOGY

This chapter includes a description of the research procedures involved in the present study including descriptions of the sample, the instrument, interview sessions, data gathering procedures, and data analysis procedures.

3.1 Sample

The sample for this study consists of 151 Korean students: 49 sixth-grade students in one class from one elementary school; 53 eighth-grade students in one class from one junior high school; and 49 tenth-grade students in one class from one senior high school. These classes were randomly selected from each grade. These schools are located in Kongju City, in the northwestern part of South Korea. Kongju City is located in a semi-urban area. It has a population of over 80,000. The economic and social status of the city are at the medium level and the educational status could be considered at the middle level, in relation to the Korean national norm. The elementary school from which students were selected is composed of students of both sexes. The students consist of 24 boys and 25 girls. The junior high school and senior high school are composed of students of one sex (male). It is traditional in Korean society that elementary schools are integrated by sexes, and the junior and senior high schools are segregated by sex. In this study,
the elementary and junior high schools are public schools, and the senior high school is a private school.

Students from grades 6, 8, and 10 were selected to explore the degree to which naive theories change as the amount and types of science study changes. Most Korean 6th-grade students are 12 years old. These students are taught science as part of an integrated science curriculum for 2-4 hours a week. Most Korean 8th-grade students are 14 years old. These students are taught science as part of a combined science curriculum. More time (3-4 hours a week) is devoted to earth science in junior high schools than in elementary schools in Korea. Most Korean 10th-grade students are 16 years old. These students are taught science as a separate science curriculum for 4-8 hours a week. Much more time is devoted to science in senior high schools than in junior high and elementary schools.

Three different kinds of textbooks (integrated science textbook for the elementary school level, combined science textbook for the junior school level, and separate earth science textbook for the senior school level) are detailed in Table 3. For each textbook, chapter, grade, earth science content, and topics relevant to this study are given. From Table 3, it can be seen that:

1. Earth science topics are taught as an integrated science during elementary school, a combined science during junior high school, and a separate earth science during senior high school in Korea.

2. Korean students begin to learn the earth science concepts very early in the elementary school.
3. By end of sixth grade, Korean students have been taught natural phenomena such as the gravity, day/night cycle, phases of the Moon, and change in seasons which are topics in the present study.

4. Korean 8th-grade students spend additional time on gravity, but no additional time on the day/night cycle, phases of the Moon, and change in seasons.

5. Korean 10th-grade students spend additional time on the concepts of gravity, day/night cycle, and change in seasons, but no additional time on the phases of the Moon.

6. Korean textbooks of the junior high and senior high school include more abstract concepts in the form of numerical formulas and quantitative relationships between variables.

The Ministry of Education, which is responsible for education administration in Korea, has an important role in adjusting the curriculum topics at the national level and in creating the three textbooks for elementary, junior high, and senior high school.
Table 3.

Earth Science Content in Integrated Science, Combined Science, and Separate Earth Science Textbooks

Integrated Science Textbook (Ministry of Education, 1988b)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chapter</th>
<th>Earth Science Content</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VI (1)</td>
<td>Summer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VIII (2)</td>
<td>Winter</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>V (1)</td>
<td>Air</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II (2)</td>
<td>Day and Night</td>
<td>Day</td>
</tr>
<tr>
<td>3</td>
<td>V (1)</td>
<td>Weather</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III (2)</td>
<td>Rocks and Soils</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>II (1)</td>
<td>Rivers and Oceans</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II (2)</td>
<td>Geological Strata and Fossils</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>III (1)</td>
<td>Weather Changes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III (2)</td>
<td>Force and Motion</td>
<td>Gravity</td>
</tr>
<tr>
<td></td>
<td>III (2)</td>
<td>Motions of the Earth and the Moon</td>
<td>Moon</td>
</tr>
<tr>
<td>6</td>
<td>I (1)</td>
<td>Volcanos and Earthquakes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II (2)</td>
<td>The Changing of the Seasons</td>
<td>Seasons</td>
</tr>
</tbody>
</table>

Combined Science Textbook (Ministry of Education, 1988c)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chapter</th>
<th>Earth Science Content</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>I</td>
<td>Atmosphere and Water Cycle</td>
<td>Gravity</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>Forces and Motion</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>I</td>
<td>The Earth's Surface and Changes</td>
<td>Gravity</td>
</tr>
<tr>
<td>9</td>
<td>III</td>
<td>Earth and Space</td>
<td>Day, Moon, Seasons</td>
</tr>
</tbody>
</table>

Separate Earth Science Textbook (Ministry of Education, 1988d)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chapter</th>
<th>Earth Science Content</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>I</td>
<td>Earth as a Planet</td>
<td>Gravity, Day, Seasons</td>
</tr>
<tr>
<td>11</td>
<td>II</td>
<td>Atmosphere and Changing Ocean</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>III</td>
<td>Changing Earth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>History of the Earth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>Exploring the Universe</td>
<td>Moon</td>
</tr>
</tbody>
</table>

Gravity: Gravity; Day: Day/night cycle; Moon: Phase of the Moon; Seasons: Change in seasons (1): 1st semester textbook (2): 2nd semester textbook
In addition, a sample of fifteen students were selected to be interviewed: 5 sixth-grade students from one elementary school; 5 eighth-grade students from one junior high school; and 5 tenth-grade students from one senior high school. The students were chosen by the researcher in terms of persistence of naive theories and science achievement scores. Of the students interviewed at each grade level, 2 students had high science achievement scores, 2 had average science achievement scores, and 1 had a low science achievement score as measured by part of teacher prepared midterm examinations. Table 4 includes the distribution of subjects for the INTTES and interviews.

Table 4

Distribution of Subjects

<table>
<thead>
<tr>
<th></th>
<th>6th</th>
<th>8th</th>
<th>10th</th>
</tr>
</thead>
<tbody>
<tr>
<td>open-ended written</td>
<td>49</td>
<td>53</td>
<td>49</td>
</tr>
<tr>
<td>questions (INTTES)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interview</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

3. 2 Instrument

One instrument, called Identification of Naive Theories Test in Earth Science (INTTES) was developed for this study (see Appendix A). The instrument, based on the review of literature and the researcher's teaching experience, serves as a means of obtaining
information about the students' naive theories of natural phenomena in earth science through open-ended written questions. A Korean version of INTTES (see Appendix B) was distributed to three intact classes for the assessment: 49 elementary school students in sixth grade; 53 junior high school students in eighth grade; 49 senior high school students in tenth grade.

The INTTES includes 5 items: two items on gravity in which gravity (I) relates to the direction of gravity and gravity (II) relates to the relationship between gravity and the position on the Earth's surface, one on the day/night cycle, one on the phases of the moon, and one on the change in seasons. Items one and two were patterned after items used by Nussbaum and Novak (1976) with some modification. Items three, four, and five were constructed by the researcher. A summary of concepts (topics) included in this study and questions (tasks) related to these concepts (topics) is given in Table 5.
### Table 5.

**Summary of Concepts (Topics) Included in This Study and Questions (Tasks) Related to These Concepts (Topics)**

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Concepts/Topics</th>
<th>Questions/Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A girl standing on the real Earth is going to drop a rock.</td>
<td>In which direction would the rock fall?</td>
</tr>
<tr>
<td>2.</td>
<td>Two bottles on the North pole are moved to the South pole.</td>
<td>What happens to the position of the bottles and to the water in the bottles?</td>
</tr>
<tr>
<td>3.</td>
<td>Day/night cycle</td>
<td>What causes the day/night cycle?</td>
</tr>
<tr>
<td>4.</td>
<td>Phases of the moon</td>
<td>Why do the phases of the Moon seem to change?</td>
</tr>
<tr>
<td>5.</td>
<td>Change in seasons</td>
<td>What causes the change in seasons?</td>
</tr>
</tbody>
</table>

*: Gravity topics.

### 3. 3 Interview Settings

The purpose of interviews in this study was to investigate students' naive theories which might be overlooked by the INTTES, clarify the nature of these naive theories, and to validate the INTTES. Interviews were also used to attempt to identify the sources of naive theories. Each interview was based on review of the student's responses to the items on the INTTES. An interview protocol was established. Two drafts of interview protocol were tested on a reference group of 2 seventh-grade Korean students whom the researcher had known personally. After careful examination of the student responses, the final interview protocol
(see Appendix C) was developed. It includes five major tasks similar to the INTTES.

Validity in qualitative studies is interpreted as credibility about the findings and interpretations for establishing true value (Patton, 1991). That is, validity refers to the extent to which the interpretations reflect and portray the participants' meanings accurately. Patton presents several ways to establish validity including prolonged engagement, triangulation (sources, methods, and investigators), peer debriefing, and member check. Validity for this dissertation study was enhanced by the use of a variety of methods: open-ended written questions (IN TTES), interviews, and participants' drawings. In addition, frequent peer debriefing was used to establish validity.

Reliability was checked by two Korean graduate students at The Ohio State University. One Korean graduate student reviewed key words, translations of these words from Korean into English, and categorization of these words into three different Models (Scientific Model, Naive Model, or "No" Model) for all student responses which were selected, translated, and categorized by the researcher.

Another Korean graduate student reviewed the results of the procedures mentioned above for the randomly selected 15 student responses (5 at each grade level). There was 97% agreement between the researcher and the graduate student for the way in which key words were categorized into three different Models. The 3% differences lay primarily in the complex student responses.
After some discussion, the graduate student agreed with the researcher for the way in which key words were categorized into three different Models.

3. 4 Data Gathering Procedures

The methods used in the dissertation study were the same as those used in the pilot study. The methods were to administer the INTTSES first, followed by the interviews. The researcher visited each of the schools chosen and administered the INTTSES between July 30, 1991 and August 5, 1991. On item one of the INTTSES, participants were asked to draw a line showing where the rock would fall, to explain their answer, and to indicate their sources of knowledge (see Appendix B). In item two, the participants were asked to draw a picture to illustrate what happens to the bottles and the water in the bottles, to explain their answer, and to indicate their sources of knowledge (see Appendix B). In items three, four, and five participants were asked to explain their answers with words and drawings and to indicate their sources of knowledge (see Appendix B). Participants were allowed to ask questions during the INTTSES examination process so that the researcher could confirm that the participants understood the directions and the items. Participants were allowed as much time as needed. All students finished within 30 minutes.

After a lapse of one week, interviews began. The interview participants were taken to Kongju National University located at Kongju City. The interviews were conducted over a two-day period,
the 6th-grade students on the first day and the 8th- and 10th-grade students on the second day. To help establish communication and build trust with the researcher, participants were taken to the planetarium. In the planetarium, participants were told about astronomy and different kinds of telescopes.

The researcher interviewed the students individually. While not being interviewed, the students were given the opportunity to watch television in another room. The interview consisted of a series of tasks on gravity, the day/night cycle, the phases of the Moon, and the change of seasons. For questions 1 and 2 on gravity, the participants were shown the cards from the INTTES items to stimulate discussion. In question 1, the participants were asked to tell where the rock would fall, explain their reason, and indicate their sources of knowledge. In question 2, the participants were asked to tell what happens to the position of the bottles and to the water in the bottles, explain their reasons, and indicate their sources of knowledge. For questions 3, 4, and 5, participants were asked to explain a series of questions on the day/night cycle, the phases of Moon, and the change of seasons, and they were asked to indicate their sources of knowledge. For these questions, the situations were presented to the students by referring to actual experience. For example, for the question on the change in seasons, the researcher began the discussion by stating that "There is summer, autumn, winter, and spring". "What season is it now?". All interviews were tape-recorded and transcribed. The transcriptions are given in Appendix D.
3. Data Analysis Procedures

Data were analyzed related to the INTTES questions presented in this chapter and the research questions in Chapter I.

The items (questions) were analyzed in terms of research questions one through three. For these questions, key phrases within students' answers were identified on the INTTES across items (questions). For the 15 students who responded to both the INTTES and to the interviews, if students' answers on the INTTES were not consistent with those in the interview, students' interview answers were used in the data analysis. Since the interview was based upon a review of the students' responses on the INTTES, the researcher felt that the students' interview answers provided more information. The key phrases were grouped into the different categories: Scientific Model, Naive Model, or "No" Model. This procedure was based on criteria used by Vosniadou (1989) where each participant's ideas were classified as either Intuitive Model or Scientific (Copernican) Model and Anderson and Smith (1986) where each participant's ideas were classified as either naïve propositions or scientific propositions. According to the criteria used by both Vosniadou and Anderson and Smith, the Scientific Model refers to student responses that are consistent with scientific theory, the Naive Model refers to student responses that are inconsistent with beliefs commonly accepted by scientists, and the "No" Model refers to questions or situations to which students have no response. The
criteria used in this study to classify responses as Scientific Model or Naive Model are shown in Table 6.

Table 6.

Examples of Criteria for Naive Model and Scientific Model

<table>
<thead>
<tr>
<th>Issue</th>
<th>Naive Model</th>
<th>Scientific Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity</td>
<td>Up/down</td>
<td>Toward the center of Earth</td>
</tr>
<tr>
<td>Day/night cycle</td>
<td>Sun's movement</td>
<td>Earth's rotation (movement)</td>
</tr>
<tr>
<td>Phases of Moon</td>
<td>Moon blocked by clouds, etc.</td>
<td>Moon's revolution</td>
</tr>
<tr>
<td>Change of seasons</td>
<td>Distance between Sun and Earth, etc.</td>
<td>Tilt of the Earth axis</td>
</tr>
</tbody>
</table>

Research questions one and two were analyzed to explore how Korean students' conceptions about natural phenomena in earth science related to Grade Level and Achievement Level are distributed across the Scientific, Naive, and "No" Model categories.

Korean students were selected from grades 6, 8, and 10 and grouped into three achievement groups (low, average, and high), based on science achievement scores which were part of the midterm examinations. The tests were prepared by the teachers and were not standardized. Different achievement tests were used for each grade level. The science test for sixth grade was administered by the classroom teacher. The 8th-grade and 10th-grade science
tests were administered by the science teachers. To classify the students by Achievement Level, students who scored in the lowest 33% of their grade level were categorized as "low achievement", in the highest 33% as "high achievement", and the remaining students as "average achievement".

In order to investigate 6th-, 8th-, and 10th-grade students' naive theories (Models) about natural phenomena in earth science, the naive theories (Models) were grouped into categories and totals determined (Research Question 3).

In response to research question 4 about the sources of naive theories as perceived by the students, the interview sample responses (N=15) related to the sources of their beliefs, both during the interview and on INTTES, were categorized as everyday experience, teachers, textbooks, instructional/general television programs, and other books as suggested by Ivowi and Oludotun (1987).

To validate the open-ended written questions (INTTES), key phrases within students' answers were identified through the INTTES and interview settings and then compared. The subjects used for comparing the student responses to the INTTES and to the interview settings were 15 students who had responses to both the INTTES and the interview settings (research question 5).

A microcomputer program, Filemaker Plus, for the Macintosh was used to count responses and to construct bar graphs related to each Model. The SPSS (Statistical Package for the Social Sciences) program was used to compute chi-square statistics for Grade Level
by Model and Achievement Level by Model contingency tables. The z-test for the differences between proportions between Grade Levels and between Achievement Levels was computed to follow up significant chi-square statistics.
CHAPTER IV
RESULTS AND DISCUSSION

This chapter presents the results of the study in combination with the items (questions) posed in Chapter III and research questions posed in Chapter I. It is divided into nine sections: 1) gravity (I); 2) gravity (II); 3) the day/night cycle; 4) the phases of the Moon; 5) the change in seasons; 6) overall summary of findings; 7) the sources of naive theories (Models); 8) a comparison of student responses to the open-ended written questions (INTTES) and to the interview settings; and 9) the discussion of the results.

The research questions presented in Chapter I are the following:

1) How are Korean 6th-, 8th-, and 10th-grade students' conceptions about selected natural phenomena in earth science distributed across the Scientific, Naive, and "No" Model categories?

2) How are Korean high, average, and low achievement students' conceptions about selected natural phenomena in earth science distributed across the Scientific, Naive, and "No" Model categories?

3) What are Korean 6th-, 8th-, and 10th-grade students' naive theories about selected natural phenomena in earth science?

4) To what sources do Korean students attribute naive
theories (Models) about selected natural phenomena in earth
science?

5) How do student responses to an open-ended written question
format (INTTES) compare to the responses to an interview
format for identifying students' naive theories?

The following sections include data related to the first three
research questions for each item. For each question the frequency
distribution of responses to the INTTES is given in the form of a bar
graph. The responses are categorized by Model by Grade Level and by
Model by Achievement Level. The bar graph is followed by a
contingency table in which the percentages of responses within
Grade Levels are given, along with the identification of the
significant differences in proportion of responses across Grade
Level and Achievement Level. The total percentages with Grade
Level and Achievement Level may be slightly higher or lower than
100% due to rounding.

To test difference between proportions of Grade Levels and
Achievement Levels, a formula (Freund & Smith, 1986) testing
whether an observed difference between two sample proportions can
be attributed to chance, or whether it is statistically significant
was used. According to the formula, the critical difference between
proportions is 0.14 at p<0.05 and 0.18 at p<0.01 for this size sample.
Due to the number of significance tests, those differences which are
significant at p<0.01 level were used to identify potential trends.

A categorization of students' response types to the INTTES by
Grade Level and a description of the interview data related to the question follows the graphs and tables for each item.

The rationale for presenting a categorization of students' response types by Grade Level rather than by Achievement Level is that: 1) Grade Level and Achievement Level data were very similar; and 2) Grade Level results directly address pedagogical concerns such as time differences spent in class on science and textbook differences in this study.

4. 1 Gravity (I)

Question: A girl has a rock in her hand and she is going to drop the rock. In which direction would the rock fall? Explain your answer.

4. 1. 1 How are Korean 6th-, 8th-, and 10th-grade Students' Conceptions about Gravity (I) Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the gravity (I) question classified by Grade Level according to Model is shown in Figure 1.
In this figure, the Scientific Model for gravity (I) is that the rock falls toward the center of the Earth because gravity pulls the rock down toward the center of the Earth. The Naive Model category includes those student responses that are inconsistent with scientific theory, and the "No" Models are used for cases in which students did not provide any responses to this question.

Figure 1 and Table 7 show that the majority of all students at all three Grade Levels held the Scientific Model (76-91%) with the 8th-grade students (91%) having a significantly greater ($p<0.05$) tendency toward Scientific Model than the 6th-grade students (76%). A Naive Model was reflected by a small number of students (6-24%) with the 6th-grade students (24%) having a significantly greater ($p<0.01$) tendency toward Naive Model than the 8th-grade students (6%). The incidence of these Models did not show a linear trend related to Grade Level. For this question, the chi-square analysis
did not show a statistically significant overall pattern \( (x^2=9.17, p=0.057) \).

Table 7
**Contingency Tables Comparing Models with Each Grade Level for Gravity (I)**

<table>
<thead>
<tr>
<th>Model</th>
<th>6th grade (n=49)</th>
<th>8th grade (n=53)</th>
<th>10th grade (n=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;No&quot; Model</td>
<td>0%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Naive Model</td>
<td>24%</td>
<td>6%</td>
<td>12%</td>
</tr>
<tr>
<td>Scientific Model</td>
<td>76%</td>
<td>91%</td>
<td>86%</td>
</tr>
</tbody>
</table>

\[ x^2=9.17, p=0.057 \]

4. 1. 2 How are Korean High, Average, and Low Achievement Students' Conceptions about Gravity (I) Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the gravity (I) question classified by Achievement Level according to Model is shown in Figure 2. The categories of the Scientific Model, Naive Model, and "No" Model for this question were used the same way in this section as in section 4. 1. 1.
Figure 2 and Table 8 show that the majority of all three achievement groups held the Scientific Model (80-86%), while a smaller number of all three achievement students reflected a Naive Model (12-18%). The incidence of these Models did not show a linear trend related to Achievement Level. For this question, the chi-square analysis did not show an overall statistically significant pattern ($\chi^2=0.92$, $p=.921$).
Table 8

Contingency Tables Comparing Models with Each Achievement Level for Gravity (I)

<table>
<thead>
<tr>
<th></th>
<th>&quot;No&quot; Model</th>
<th>Naive Model</th>
<th>Scientific Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>low achievement</td>
<td>2%</td>
<td>12%</td>
<td>86%</td>
</tr>
<tr>
<td>(n=52)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average achievement</td>
<td>2%</td>
<td>18%</td>
<td>80%</td>
</tr>
<tr>
<td>(n=51)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high achievement</td>
<td>2%</td>
<td>12%</td>
<td>85%</td>
</tr>
<tr>
<td>(n=48)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ x^2 = 0.92, p = .921 \]

4. 1. 3 What are Korean 6th-, 8th-, and 10th-grade Students' Naive Theories (Models) about Gravity (I)?

Percentages of 6th-, 8th-, and 10th-grade student responses to the question about the gravity (I) are shown in Table 9. Student responses were categorized into 8 response groups. The student responses were presented in order from the most frequent response group down to the least frequent group except for the "No" Model. When frequencies of a response group are equal, the group with more upper Grade Level student responses is given first.
### Table 9

**Percentages of Student Responses to the Question about Gravity (I) by Grade**

<table>
<thead>
<tr>
<th>Response Group</th>
<th>Grade</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don't know</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

*: Scientific Model  **: Naive Model  ***: "No" Model
Response group 1 (*) represents those responses which are correct results combined with correct reasons and includes 76% of 6th-grade, 91% of 8th-grade, and 86% of 10th-grade students, who believed that the rock would fall toward the center of the Earth. With regard to reasons given for their answers, they explained that gravity would pull the rock down toward the center of the Earth (Scientific Model).

Response group 1 (**) represents those responses which are correct results combined with incorrect reasons and includes 8% of sixth grade and 2% of tenth grade, who believed that the rock would fall toward the center of the Earth. With regard to reasons given for their answers, 6% of 6th-grade students stated that pressure would pull the rock down toward the center of the Earth, 2% of 6th-grade students indicated that the rock would fall down toward the center of the Earth because there is no air, and 2% of 10th-grade students explained that gravity and the Earth's rotation pull the rock down toward the center of the Earth (Naive Model).

Response group 2, containing 8% of 6th-grade and 6% of 8th-grade students, believed that the rock would fall downward in relation to the orientation of a page of print (see response group 2 in Table 9). Of these students, 6% of 6th-grade and 6% of 8th-grade students explained that it was natural that if we drop something in space, it would fall downward in relation to the orientation of a page of print (Naive Model). Two percent of 6th-grade students reasoned that the Earth's rotation would cause the rock to fall downward in relation to the orientation of a page of print (Naive
A portion of the interview with one student (sixth grade) in response group 2 who said that the rock would naturally fall downward (R: Researcher S: Student) follows:

R: What is this (pointing at the picture)?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you remember the question?
S: If the person drops the rock, in which direction would the rock fall?
R: Very good. In which direction?
S: The rock would fall downward (students dropped an eraser as an example).
R: Where is the North Pole?
S: Here.
R: Where is the Equator?
S: (hesitating)
R: Here. Okay?
S: Yes.
R: If the person drops the rock here, in which direction would the rock fall?
S: (hesitating)
R: Where did you first learn about this?
S: That's just what I thought.
R: Can you give me an example of gravity in everyday life?
S: When I drop an eraser, it falls down.
R: Okay.

Transcripts of the interview indicate that the interviewee expects the rock to fall downward which she illustrates in terms of "down" on the page, not toward the center of the Earth drawing. The interviewee apparently learns this from experience involving directions (up and down) in reference to books and papers.

Response group 3, which includes 6% of 10th-grade students, believed that the rock would fall at an angle toward the surface of the Earth (see response group 3 in Table 9). They reasoned that the rock would fall at an angle toward the surface of the Earth because of the Earth's rotation (Naive Model). A portion of the interview with one student (tenth grade) in response group 3 who said that the rock would fall at an angle toward the surface of the Earth (R: Researcher S: Student) follows:

R: You saw this picture, right?
S: Yes.
R: Can you draw another diagram here?
S: Yes. (drawing a diagram)
R: What is this?
S: The Earth.
R: What is this?
S: A person.
R: What is this?
S: A rock.
R: Do you suppose the size of the person relative to Earth and the rock is reasonable?
S: No.
R: What is your idea about this?
S: The Earth is larger than this.
R: When the person is going to drop the rock, in which direction would the rock fall?
S: Toward the center of the Earth.
R: And then?
S: Because the Earth rotates from the west to the east, the rock falls like this. (pointing to the diagram).
R: You say that the Earth rotates from the west to the east, the rock falls like that?
S: Yes.
R: The rock does not fall toward the center of the Earth?
S: It may fall at an angle toward the surface of the Earth because of the Earth's rotation.
R: Does the fall of the rock result from gravity?
S: Yes.
R: What do you mean by gravity?
S: The force that the planets including the Earth attract objects.
R: Can you give me a good example of gravity in everyday life?
S: I think that gravity is related to the fact that a person stands on the Earth.
R: What happens to a person if there is no gravity on the Earth?
S: He will fall down.

The interviewee indicates that the force of gravity as related to the center of the Earth but the Earth's rotation is a factor which complicates the explanation.

Response group 4, which includes 4% of 10th-grade students believed that the rock would fall in a curved path as shown in response group 4 in Table 9. Two percent of 10th-grade students reasoned that there is a Coriolis effect owing to the Earth's rotation (Naive Model). Two percent of 10th-grade students reasoned that there is no air to pull the rock down in any direction (Naive Model).

Response group 5, consisting of 4% of 6th-grade students, believed that the rock would remain in the original position (see response group 5 in Table 9). Of these students, 2% of the students reasoned that there is no gravity to pull the rock down (Naive Model) and 2% of the students reasoned that there is no air to pull the rock down (Naive Model).

Response group 6, consisting of 2% of 6th-grade students, believed that the rock would fall away from the surface of the Earth (see response group 6 in Table 9). The reason given was that there is no air around the Earth (Naive Model).

Response group 7, which includes 2% of 6th-grade students, believed that the rock would fall down and move in a circular path around the Earth (see response group 7 in Table 9). The reason given was that the rock would fall down and that the Earth is circular in
Response group 8, which includes 4% of 8th-grade and 2% of 10th-grade students, did not provide any responses to this question ("No" Model).

4. 1. 4 Summary

A higher percentage of the students at all three Grade Levels and at all three Achievement Levels holds the Scientific Model, while a smaller percentage of the students holds a Naive Model for gravity (I).

The incidence of these Models did not show a linear trend related to Grade Level and Achievement Level for this question. Chi-square analysis did not show an overall statistically significant pattern across Grade Level and Achievement Level within Model Levels.

There are two general types of naive conceptions: 1) correct results combined with incorrect reasons; and 2) incorrect results combined with incorrect reasons. Most of the Naive Models include both incorrect results and incorrect reasons. The incorrect reasons are classified as the relationships between gravity and: 1) air/pressure; 2) shape of the Earth; and 3) movement of the Earth.

Interview transcripts indicate that there is some tendency for 6th-grade students to perceive air as a relevant factor, while 10th-grade students tend to identify more complex relationships between the Earth's rotation and gravity.
4. 2 Gravity (II)

Question: Two bottles are at the North Pole. One of them is closed and the other is open. Both are half-filled with water. Suppose that a girl takes the bottles to the South Pole. What happens to the positions of the bottles and to the water in the bottles? Explain your answer.

4. 2. 1 How are Korean 6th-, 8th-, and 10th-grade Students' Conceptions about Gravity (II) Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the gravity (II) question classified by Grade Level according to Models is shown in Figure 3. The Scientific Model for gravity (II) is that the bottom of the bottles would be toward the center of the Earth and the water would remain at the bottom of the bottles due to the attraction (gravity) of objects toward the Earth's center. The Naive Model category includes those student responses that are inconsistent with scientific theory, and the "No" Models are used for cases in which students did not provide any responses to this question.
Figure 3 and Table 10 show that the majority of all students at all three Grade Levels held the Scientific Model (55-90%) with the 10th-grade students (90%) and the 8th-grade students (81%) having a significantly greater (p<0.01) tendency toward Scientific Model than the 6th-grade students (55%). A Naive Model was reflected by a smaller number of students (6-41%) with the 6th-grade students (41%) having a significantly greater (p<0.01) tendency toward Naive Model than the other grades (6-8%).

There appears to be a progressive increase in the percentage of students holding Scientific Model from the 6th-grade (55%) to the 8th-grade (81%) to the 10th-grade students (90%) and a corresponding decrease in the percentage of the students holding Naive Model from the 6th-grade (41%) to the 8th-grade (8%) to the 10th-grade students (6%). For this question, the chi-square analysis did show a statistically significant overall pattern ($\chi^2=28.34$, p = .00001).
Table 10

Contingency Tables Comparing Models with Each Grade Level for Gravity (II)

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>&quot;No&quot;</th>
<th>Naive</th>
<th>Scientific</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th grade</td>
<td>4%</td>
<td>41%</td>
<td>55%</td>
</tr>
<tr>
<td>(n=49)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8th grade</td>
<td>11%</td>
<td>8%</td>
<td>81%</td>
</tr>
<tr>
<td>(n=53)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10th grade</td>
<td>4%</td>
<td>6%</td>
<td>90%</td>
</tr>
<tr>
<td>(n=49)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

χ²=28.34, p= .00001

4. 2. 2 How are Korean High, Average, and Low Achievement Students' Conceptions about Gravity (II) Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the gravity (II) question classified by Achievement Level according to Model is shown in Figure 4. The categories of Scientific Model, Naive Model, and "No" Model for this question were used the same way in this section as in section 4. 2. 1.
Figure 4 and Table 11 show that the majority of all three Achievement Levels held the Scientific Model (60-90%) with the high Achievement Level (90%) and the average Achievement Level (78%) having a significantly greater (p<0.01) tendency toward Scientific Model than the lower Achievement Level (60%), while a smaller number of all three Achievement Levels reflected a Naive Model (10-27%) with the lower Achievement Level (27%) having a significantly greater (p<0.05) tendency toward Naive Model than the high Achievement Level (10%).

There appears to be a progressive increase in the percentage of the students holding Scientific Model from the low Achievement Level (60%) to the average Achievement Level (78%) to the high Achievement Level (90%) and a corresponding decrease in the percentage of the students holding Naive Model from the low Achievement Level (27%) to the average Achievement Level (16%) to the high Achievement Level (10%). For this question, the chi-square
analysis did show a statistically significant overall pattern \( \chi^2 = 13.96, p = .00742 \).

Table 11

**Contingency Tables Comparing Models with Each Achievement Level for Gravity (II)**

<table>
<thead>
<tr>
<th>Achievement Level</th>
<th>&quot;No&quot; Model</th>
<th>Naive Model</th>
<th>Scientific Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (n=52)</td>
<td>14%</td>
<td>27%</td>
<td>60%</td>
</tr>
<tr>
<td>Average (n=51)</td>
<td>6%</td>
<td>16%</td>
<td>78%</td>
</tr>
<tr>
<td>High (n=48)</td>
<td>0%</td>
<td>10%</td>
<td>90%</td>
</tr>
</tbody>
</table>

\( \chi^2 = 13.96, p = .00742 \)

4. 2. 3 What are Korean 6th-, 8th-, and 10th-grade Students' Naive Theories (Models) about Gravity (II)?

Percentages of 6th-, 8th-, and 10th-grade student responses to the question about the gravity (II) are shown in Table 12. Student responses were categorized into 7 response groups. The student responses were presented in order from the most frequent response group down to the least frequent group except for the "No" Model. When frequencies of a response group are equal, the group with more upper Grade Level student responses is given first.
Table 12
Percentages of Student Responses to the Question about Gravity (II) by Grade

<table>
<thead>
<tr>
<th>Response Group</th>
<th>Grade</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>1.</td>
<td>55</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>* (correct result/correct reason)</td>
<td>**(correct result/incorrect reason)</td>
</tr>
<tr>
<td>2.</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>7. I don't know</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>***</td>
</tr>
</tbody>
</table>

*: Scientific Model  **: Naive Model  ***: "No" Model
Response group 1 (*) represents those responses which are correct results combined with correct reasons and includes 55% of 6th-grade, 81% of 8th-grade, and 90% of 10th-grade students, who believed that the bottom of the bottles would be toward the center of the Earth and the water in the bottles would remain at the bottom of the bottles. With regard to reasons given for their answers, they explained that gravity would cause the bottom of bottle to be toward the center of the Earth and the water in the bottles to be at the bottom of the bottles (Scientific Model).

Response group 1 (**) represents those responses which are correct results combined with incorrect reasons and includes 17% of 6th-grade, 4% of 8th-grade, and 4% of 10th-grade students, who believed that the bottom of the bottles would be toward the center of the Earth and the water would remain in the original state. With regard to reasons given for their answers, 14% of sixth grade and 4% of eighth grade in this response group claimed that the water in the bottles would be frozen at the South Pole and that the bottom of the bottles would be toward the center of the Earth. These students did not have an explanation as to why the bottom of the bottles would be toward the center of the Earth (Naive Model). Also, 4% of 10th-grade students in this response group claimed that the water in the bottles would be frozen at the South Pole because the South Pole is colder than the North Pole and that the bottom of the bottles would be toward the center of the Earth. These students did not explain why the bottom of the bottles would be toward the center of the Earth (Naive Model). Two percent of 6th-grade students reasoned
that a lack of air would cause the water to stay at the bottom of the bottles; these students also did not explain why the bottom of the bottles would be toward the center of the Earth (Naive Model). A portion of the interview with one student (eighth grade) in response group 1 who claimed that the water in the bottles would be frozen at the South Pole and that the bottom of the bottles would be toward the center of the Earth (R: Researcher S: Student) follows:

R: Is this the Earth?
S: Yes.
R: And this?
S: The South Pole.
R: And this?
S: The North Pole?
R: And this?
S: Two bottles of water.
R: One bottle is open? The other bottle is closed?
S: Yes.
R: What is the question?
S: (students recalls this question) If we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: Positions of the bottles?
S: The same.
R: What about the water in the bottles?
S: Frozen.
R: Frozen?
S: Yes.

R: If the bottles are taken to the Equator, What happens to the water in the bottles?
S: I think that the water remains in the original state.
R: Why?
S: Gravity.
R: What happens to the water at the South Pole?
S: Frozen.

Transcripts of the interview indicate that the student perceives the water in the bottles to be frozen at the South Pole but not at the North Pole. The student would expect the bottom of the bottles to be toward the center of the Earth and the water to remain at the bottom of the bottle due to the cold temperature at the South Pole.

Response group 2 includes 10% of 6th-grade and 2% of 8th-grade students who believed that the bottom of the bottles would be toward the center of the Earth, that the water in the closed bottle would remain at the bottom of the bottle, and that the water in the open bottle would be gone or spill out (see response group 2 in Table 12). The explanations given were as follows: 1) 6% of 6th-grade students indicated that the bottom of the bottles would be toward the center of the Earth and since there is no cap for one of the bottles, there would be no water in the open bottle (Naive Model); 2)
2% of 6th-grade students indicated that the South Pole was warmer than the North Pole, and so there would be no water in the open bottle (Naive Model). Perhaps this is related to a change in phase from solid to liquid, therefore allowing the water to spill out; 3) 2% of 6th-grade students indicated that the water in the bottles depended upon the cap, and so the water in the closed bottle would remain in the original state and the water in the open bottle would empty from the bottle (Naive Model); 4) 2% of 8th-grade students reasoned that the water in the closed bottle was covered by a cap and so would be frozen, but the water in the open bottle was not covered by a cap, and so the water would empty from the bottle (Naive Model). The students in this response group did not mention that gravity would cause the bottles to be toward the center of the Earth.

Response group 3 includes 12% of 6th-grade students who believed that the bottom of the bottles would be toward the center of the Earth, that the water in the closed bottle would be at the top, and that there would be no water in the open bottle (see response group 3 in Table 12). The students reasoned that there is air around the Earth; therefore, the water in the closed bottle would be at the top and there would be no water in the open bottle (Naive Model). The students in this response group did not mention gravity as the reason that the bottom of the bottles would be toward the center of the Earth.

Response group 4 includes 2% of 10th-grade students who believed that the bottom of the bottles would be toward the center
of the Earth, that the water in the closed bottle would remain in the original state, and that the volume of water in the open bottle would be less (see response group 4 in Table 12). The reason given was that when the girl took the bottles to the South Pole, the girl would pass the equator (Naive Model). The student did not mention why the bottom of the bottles would be toward the center of the Earth.

Response group 5, which also includes 2% of 8th-grade students, stated that the bottom of the bottles would be toward the center of the Earth and that the water in both bottles would be at the top (see the response group 5 in Table 12, Naive Model). The students did not give a reason for the answer.

Response group 6, which includes 2% of 6th-grade students, believed that the bottom of the bottles would be toward the center of the Earth, that the water in the closed bottle would remain in the original state, and that the water in the open bottle would be at the top (see response group 6 in Table 12). The reason given was that there is no air around the Earth. Therefore, the lack of air would cause the water in the closed bottle to remain in the original state and the water in the open bottle would be at the top (Naive Model). The student did not explain why the bottom of the bottles would be toward the center of the Earth.

Response group 7 includes 4% of 6th-grade, 11% of 8th-grade and 4% of 10th-grade students who did not provide any responses to this question ("No" Model).
4. 2. 4 Summary

A higher percentage of the students at all three Grade Levels and at all three Achievement Levels holds the Scientific Model, while a smaller percentage of the students holds a Naive Model for gravity (II).

There are two patterns for this question: 1) a progressive increase in the percentage of the students using Scientific Models as Grade Level and Achievement Level increase; and 2) a gradual decrease in the percentage of the students using Naive Models as Grade Level and Achievement Level increase. Chi-square analysis showed an overall statistically significant pattern across Grade Level and Achievement Level within Model Levels.

There are two general types of naive conceptions: 1) correct results combined with incorrect reasons; and 2) incorrect results combined with incorrect reasons. Most of the Naive Models included both incorrect results and incorrect reasons. The incorrect reasons are classified as related to: 1) the effects of air/no air/air pressure on gravity; 2) the effects of temperature on gravity (the frozen state of the liquid in the bottles at the Poles tends to allow the students to avoid or conceal the issue as to how gravity is perceived vary as one moves from one point to another around the Earth's surface); 3) the relationship between the phases of matter and gravity (there is some indication that students perceive that gravity affects solids and liquids differently. Solids tend to behave as though gravity would hold the object against the Earth regardless of which Pole, while the liquid phase of water would spill out when
placed at the South Pole); 4) the effects that a cap on the bottle would have on gravity.

It is interesting that the students stated that freezing, evaporation, air, no air, air pressure, cap, and position around the Earth where the bottles are placed vary the influence that gravity has.

4. 3 Day/Night Cycle

Question: It is dark at night and light during the day. What causes the day and night cycle? You can explain the answer to this question using diagrams and words.

4. 3. 1 How are Korean 6th-, 8th-, and 10th-grade Students' Conceptions about the Day/Night Cycle Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the day/night cycle question classified by Grade Level according to Model is shown in Figure 5.

The Scientific Model for the day/night cycle is based upon the Earth's rotation. The Naive Model category includes those student responses that are inconsistent with scientific theory, and the "No" Models category includes used for cases in which students did not provide any responses to this question.
Figure 5 and Table 13 show that the majority of all students at all three Grade Levels held the Scientific Model (78-98%) with the 10th-grade students (98%) having a significantly greater (p<0.01) tendency toward Scientific Model than the other grades (78-81%). A Naive Model was reflected by a small number of students (2-18%) with the 6th-grade students (18%) having a significantly greater (p<0.05) tendency toward Naive Model than the 10th-grade students (2%).

There appears to be a progressive increase in the percentage of students holding the Scientific Model from the 6th-grade (78%) to the 8th-grade (80%) to the 10th-grade students (98%) and a corresponding decrease in the percentage of the students holding a Naive Model from the 6th-grade (18%) to the 8th-grade (11%) to the 10th-grade students (2%). For this question, the chi-square analysis did show a statistically significant overall pattern ($\chi^2=11.22$, $p=0.02413$).
Table 13

Contingency Tables Comparing Models with Each Grade Level for Day/Night Cycle

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>&quot;No&quot; Model</th>
<th>Naive Model</th>
<th>Scientific Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th grade (n=49)</td>
<td>4%</td>
<td>18%</td>
<td>78%</td>
</tr>
<tr>
<td>8th grade (n=53)</td>
<td>8%</td>
<td>11%</td>
<td>81%</td>
</tr>
<tr>
<td>10th grade (n=49)</td>
<td>0%</td>
<td>2%</td>
<td>98%</td>
</tr>
</tbody>
</table>

χ² = 11.22, p = .02413

4.3.2 How are Korean High, Average, and Low Achievement Students' Conceptions about the Day/Night Cycle Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the day/night cycle question classified by Achievement Level according to Model is shown in Figure 6. The categories of Scientific Model, Naive Model, and "No" Model for this question were used the same way in this section as in section 4.3.1.
Figure 6 and Table 14 show that the majority of all three Achievement Levels held the Scientific Model (69-96%) with the high Achievement Level (96%) and the average Achievement Level (92%) having a significantly greater (p<0.01) tendency toward the Scientific Model than the low Achievement Level (69%), while a smaller number of all three Achievement Levels reflected a Naive Model (4-21%) with the lower Achievement Level (21%) having a significantly greater (p<0.05) tendency toward a Naive Model than the other Achievement Levels (4-6%).

There appears to be a progressive increase in the percentage of the students holding the Scientific Model from the low Achievement Level (69%) to the average Achievement Level (92%) to the high Achievement Level (96%) and a corresponding decrease in the percentage of the students holding a Naive Model from the low Achievement Level (21%) to the average Achievement Level (6%) to the high Achievement Level (4%). For this question, the chi-square
analysis did show a statistically significant overall pattern ($x^2 = 17.48, p = .00156$).

Table 14

Contingency Table Comparing Models with Each Achievement Level for the Day/Night Cycle

<table>
<thead>
<tr>
<th></th>
<th>&quot;No&quot;</th>
<th>Naive</th>
<th>Scientific</th>
</tr>
</thead>
<tbody>
<tr>
<td>low achievement</td>
<td>10%</td>
<td>21%</td>
<td>69%</td>
</tr>
<tr>
<td>(n=52)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average achievement</td>
<td>2%</td>
<td>6%</td>
<td>92%</td>
</tr>
<tr>
<td>(n=51)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high achievement</td>
<td>0%</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>(n=48)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$x^2 = 17.48, p = .00156$

4. 3. 3 What are Korean 6th-, 8th-, and 10th-grade Students' Naive Theories (Models) about the Day/Night Cycle?

Percentages of 6th, 8th, and 10th-grade student responses to the question about the day/night cycle are shown in Table 15. Student responses were categorized into 9 response groups. The student responses were presented in order from the most frequent response group down to the least frequent group except for the "No" Model. When frequencies of a response group are equal, the group with more upper Grade Level student responses is given first.
Table 15
Percentages of Student Responses to the Question about the Day/Night Cycle by Grade

<table>
<thead>
<tr>
<th>Response Group</th>
<th>6th Grade</th>
<th>8th Grade</th>
<th>10th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Earth spins once per day and one half of the Earth is lighted</td>
<td>78%</td>
<td>81%</td>
<td>98%</td>
</tr>
<tr>
<td>2. The Earth revolves around the Sun</td>
<td>10%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>3. The Sun moves around the Earth</td>
<td>2%</td>
<td>2%</td>
<td>**</td>
</tr>
<tr>
<td>4. The Earth receives light from the Sun during the day and receives light from the Moon during the night</td>
<td>2%</td>
<td>2%</td>
<td>**</td>
</tr>
<tr>
<td>5. The Earth rotates, revolves, and the Moon revolves</td>
<td>2%</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>6. The Moon and the Sun rotate around the Earth</td>
<td>2%</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>7. The Moon blocks the Sun during the night</td>
<td>2%</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>8. Only in the daytime does the Earth receive light</td>
<td>2%</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>
| 9. I don't know | 4% | 8% | **

*: Scientific Model  **: Naive Model  ***: "No" Model

Response group 1, 78% of 6th-grade, 81% of 8th-grade, and 98% of 10th-grade students, believed that the change in the day/night cycle is due to the Earth's rotation. The students in this response group explained that the Earth rotates once per day and one half of the Earth is always lighted (Scientific Model).

Response group 2, consisting of 10% of 6th-grade, 4% of 8th-grade, and 2% of 10th-grade students, stated that the change in the day/night cycle is due to the Earth's revolution. These students
explained that when the Earth revolves around the Sun once in a year, on half of the Earth it is day time and on the other half of the Earth it is night (Naive Model). A portion of the interview with one student (sixth grade) in response group 2 who claimed that the change in the day/night cycle is due to the Earth's revolution (R: Researcher S: Student) follows:

R: Is it day or night now?
S: Day.
R: Later?
S: Night.
R: What causes day and night?
S: The Earth's revolution.
R: What do you mean by the Earth's revolution. Can you explain this using a diagram?
S: (drawing a diagram). Here is the Sun, the Moon, and the Earth. The Earth revolves around the Sun. (hesitating) The shadow of the Earth.
R: Can you explain this using a diagram again?
S: I am not sure.

Transcripts of the interview show that the perception of the time for the Earth to revolve around the Sun and the time for the day/night cycle were not apparently considered.

Response group 3, consisting of 2% of 6th-grade and 2% of 8th-grade students, believed that the change in the day/night cycle is due to the Sun's movement. The students indicated that in the
daytime the Sun rises and at night the Sun sets (Naive Model).

Response group 4, consisting of 2% of 6th-grade and 2% of 8th-grade students, explained that the change in the day/night cycle is due to the fact that the Earth receives light from the Sun during the day and receives light from the Moon during the night (Naive Model).

Response group 5 includes 2% of 8th-grade students who explained that the Earth rotates and revolves around the Sun, and the Moon revolves around the Earth (Naive Model).

Response group 6, 2% of 8th-grade students, reasoned that the Moon and the Sun rotate around the Earth (Naive Model).

Response group 7 includes 2% of 6th-grade students who credited the change in the day/night cycle to the Moon's rotation. The student explained that when the Moon rotates around the Earth, the Moon blocks sunlight during the night (Naive Model).

Response group 8, 2% of 6th-grade students, explained that the change during the day/night cycle is due to the fact that the Earth only receives light in the daytime (Naive Model).

Response group 9 includes 4% of 6th-grade and 8% of 8th-grade students who did not provide any responses to this question ("No" Model).

4.3.4 Summary

A higher percentage of the students at all three Grade Levels and at all three Achievement Levels holds the Scientific Model, while a smaller percentage of the students holds a Naive Model for
the day/night cycle.

There are two patterns for this question: 1) a progressive increase in the percentage of the students using Scientific Models as Grade Level and Achievement Level increases; and 2) a gradual decrease in the percentage of the students using Naive Models as Grade Level and Achievement Level increases. Chi-square analysis showed an overall statistically significant pattern across Grade Level and Achievement Level within Model Levels.

The general types of Naive Models are classified as follows: 1) motion of the Earth; 2) motion of the Sun; 3) sources of light; and 4) relative motion of the Earth, Moon, and Sun.

It is interesting that 2% of 6th-grade students and 2% of 8th-grade students believe the geocentric, Ptolemaic view in which the Sun moves around the Earth. Two percent of 8th-grade students reasoned that the change in the day/night cycle is due to the fact that the Earth rotates and revolves around the Sun, and the Moon revolves around the Earth. It seems that the students tend to understand the relative motion of the Earth, Moon, and the Sun, but do not know how this relates to the day/night cycle.

4. 4 Phases of the Moon

Question: From one day to the next, the Moon has different phases. Why do the phases of the Moon seem to change? You can explain the answer to this question using diagrams and words.
4. 4. 1 How are Korean 6th-, 8th-, and 10th-grade Students' Conceptions about the Phases of the Moon Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the phases of the Moon question classified by Grade Level according to Model is shown in Figure 7. The Scientific Model for the phases of the Moon is due to the Moon's revolution. The Naive Model category includes those student responses that are inconsistent with scientific theory, and the "No" Models are used for cases in which students did not provide any responses to this question.

![Bar Graph Comparison](image)

Figure 7. Comparison of Percentage of Responses to the Question on the Phases of the Moon for Each Grade Level According to Models

Figure 7 and Table 16 show a somewhat greater frequency in the use of a Naive Model as compared to the Scientific Model for 6th-grade and 10th-grade students. Of interest is the trend toward more frequent Naive Models (69%) and less Scientific Model (25%)
for 6th-grade students, less Naive Model (36%) and more Scientific Model (47%) for 8th-grade students, and more Naive Model (47%) and less Scientific Model (37%) for 10th-grade students. The 8th-grade students (47%) had a significantly greater (p<0.01) tendency toward the Scientific Model than the 6th-grade students (25%). The 6th-grade students (69%) had a significantly greater (p<0.01) tendency toward the Naive Model than the other grades (36-47%). The incidence of these Models did not show a linear trend related to Grade Level. For this question, the chi-square analysis did show a statistically significant overall pattern ($\chi^2 = 12.24$, $p = .01565$).

Table 16

Contingency Tables Comparing Models with Each Grade Level for the Phases of the Moon

<table>
<thead>
<tr>
<th></th>
<th>&quot;No&quot;</th>
<th>Naive</th>
<th>Scientific</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th grade</td>
<td>6%</td>
<td>69%</td>
<td>25%</td>
</tr>
<tr>
<td>(n=49)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8th grade</td>
<td>17%</td>
<td>36%</td>
<td>47%</td>
</tr>
<tr>
<td>(n=53)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10th grade</td>
<td>16%</td>
<td>47%</td>
<td>37%</td>
</tr>
<tr>
<td>(n=49)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\chi^2 = 12.24$, $p = .01565$
4. 4. 2 How are Korean High, Average, and Low Achievement Students' Conceptions about the Phases of the Moon Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the phases of the Moon question classified by Achievement Level according to Model is shown in Figure 8. The categories of Scientific Model, Naive Model, and "No" Model for this question were used the same way in this section as in section 4. 4. 1.

Figure 8. Comparison of Percentage of Responses to the Question on the Phases of the Moon for Each Achievement Level According to Models

Figure 8 and Table 17 show that Naive Model is slightly more common for students at all Achievement Levels: the low Achievement Level (48%); the average Achievement Level (59%); and the high Achievement Level (44%). For all Achievement Levels, the percentage of students holding Scientific Model is relatively small:
the low Achievement Level (35%); the average Achievement Level (33%); the high Achievement Level (42%). The average achievement students (59%) had a significantly greater (p<0.05) tendency toward the Naive Model than the high achievement students. The incidence of these Models did not show a linear trend related to Achievement Level. For this question, the chi-square analysis did not show a statistically significant overall pattern ($\chi^2=3.57, p= .46649$).

Table 17
Contingency Tables Comparing Models with Each Achievement Level for the Phases of the Moon

<table>
<thead>
<tr>
<th></th>
<th>&quot;No&quot; Model</th>
<th>Naive Model</th>
<th>Scientific Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>low achievement</td>
<td>17%</td>
<td>48%</td>
<td>35%</td>
</tr>
<tr>
<td>(n=52)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average achievement</td>
<td>8%</td>
<td>59%</td>
<td>33%</td>
</tr>
<tr>
<td>(n=51)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high achievement</td>
<td>15%</td>
<td>44%</td>
<td>42%</td>
</tr>
<tr>
<td>(n=48)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\chi^2=3.57, p= .46649$

4. 4. 3 What are Korean 6th-, 8th-, and 10th-grade Students' Naive Theories (Models) about the Phases of the Moon?

Percentages of 6th-, 8th-, and 10th-grade student responses to the question about the phases of the Moon are shown in Table 18. Student responses were categorized into 18 response groups. The
student responses were presented in order from the most frequent response group down to the least frequent group except for the "No" Model. When frequencies of a response group are equal, the group with more upper Grade Level student responses is given first.
Table 18  
Percentages of Student Responses to the Question about the Phases of the Moon by Grade

<table>
<thead>
<tr>
<th>Response</th>
<th>Grade</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>1. The Moon revolves</td>
<td>25</td>
<td>47</td>
</tr>
<tr>
<td>2. Differences in the sizes of the Earth's shadow</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td>3. The Earth blocks the Moon</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>4. Different amounts of light reflected by the Moon</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>5. The Earth rotates</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>6. The Earth revolves</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>7. The Earth rotates and the Moon revolves</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>8. The Moon rotates and revolves</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>9. The Earth rotates and the Moon rotates</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>10. The Moon rotates</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>11. The Earth rotates, revolves, and the Moon revolves</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>12. Different amounts of light reflected by the Earth</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>13. Relative distance of the Sun and the Moon</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>14. Changes in weather</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>15. The Moon is lit by the changes in Earth &amp; Sun</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>16. The Earth rotates and revolves</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>17. The Earth &amp; Sun provide the Moon with light and energy</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>18. I don't know</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

*: Scientific Model    **: Naive Model    ***: "No" Model
Response group 1, consisting of 25% of 6th-grade, 47% of 8th-grade, and 37% of 10th-grade students, believed that the phases of the Moon are due to the Moon's revolution. The students in this response group answered correctly that the Moon's revolution allows us to see different amounts of the lighted part of the Moon at different times (Scientific Model).

Response group 2 includes 21% of 6th-grade, 10% of 8th-grade, and 6% of 10th-grade students who reasoned that different amounts of the Earth's shadow cause the phases of the Moon at different times (Naive Model). A portion of the interview with one student (sixth grade) in response group 2 who claimed that different amounts of the Earth's shadow cause the phases of the Moon at different times (R: Researcher  S: Student) follows:

R: Do the phases of the Moon seem to change at night?
S: Yes.
R: What phases of the Moon do you see?
S: (hesitating) a full Moon, a half Moon......
R: Why do you think that the phases of the Moon seem to change at night? Can you explain this using a diagram?
S: (drawing a diagram). The Moon has phases because of the Earth's shadow.
R: (pointing to the diagram) What is the location of a full Moon and a half Moon with respect to the Earth?
S: (hesitating) If the shadow of the Earth is small, the Moon is a half Moon.
R: Can you explain this again?
S: I am not sure.
R: Why do the phases of the Moon seem to change at night?
S: (hesitating) I am not sure.

Transcripts of the interview indicate that the student believed that the Earth's shadow (related to eclipse) was responsible for the phases of the Moon.

Response group 3 includes 10% of 6th-grade, 8% of 8th-grade, and 4% of 10th-grade students who reasoned that the Earth blocks the Moon (Naive Model).

Response group 4 includes 6% of 6th-grade, 6% of 8th-grade, 9% of 10th-grade students who mentioned that different amounts of light are reflected by the Moon at different times (Naive Model). A portion of the interview with one student (sixth grade) in response group 4 who claimed that different amounts of light reflected by the Moon at different times cause the phases of the Moon (R: Researcher S: Student) follows:

R: Do the phases of the Moon seem to change at night?
S: Yes.
R: What phases of the Moon do you see?
S: A full Moon, a half Moon.
R: Why do you think that the phases of the Moon seem to change at night? Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun, the Earth, and the Moon. As far as I know, the Moon has the ability to reflect light. If the
Moon reflects light too much, it is a full Moon...

R: (pointing to the diagram) What is the location of a full Moon with respect to the Earth?
S: Here.
R: And a half Moon?
S: Here
R: You mean that the phases of the Moon result from the different amount of light reflected by the Moon?
S: Yes
R: Where did you first learn this?
S: From teachers and science textbooks.
R: Do you mean teachers or science textbooks?
S: Teachers

Transcripts of the interview indicate that the student perceived that different amounts of light are reflected by the Moon resulting in the phases of the Moon.

Response group 5, 8% of 6th-grade, 2% of 8th-grade, and 2% of 10th-grade students, credited the phases of the Moon to the Earth's rotation (Naive Model).

Response group 6, which includes 4% of 6th-grade and 8% of 8th-grade students, believed that the phases of the Moon are due to the Earth's revolution (Naive Model). A portion of the interview with one student (eighth grade) in response group 6 who claimed that the Earth's revolution causes the phases of the Moon (R: Researcher S: Student) follows:
R: We see the different phases of the Moon at night?
S: Yes.
R: Did you observe them?
S: Yes.
R: Why do the phases of the Moon seem to change at night?
S: (drawing a diagram and explaining) The Earth revolves around the Sun.
R: Where does the observer stand in your diagram?
S: At the center of the Earth.
R: At the center of the Earth?
S: I am not sure.
R: Are you confused about this question?
S: Yes.

Transcripts of the interview indicate that the student perceived that the Earth's revolution would result in the phases of the Moon but the student could not offer an explanation for how this occurs.

Response group 7 includes 4% of 6th-grade and 6% of 10th-grade students who credited the phases of the Moon to the Earth's rotation and the Moon's revolution (Naive Model).

Response group 8 includes 2% of 6th-grade and 6% of 10th-grade students who believed that the Moon's rotation and revolution results in the phases of the Moon (Naive Model).

Response group 9 includes 2% of 6th-grade and 4% of 10th-grade students who believed that the phases of the Moon are due to
the Earth's rotation and the Moon's rotation (Naive Model).

Response group 10 includes 2% of 6th-grade and 4% of 10th-grade students who believed that the Moon's rotation results in the phases of the Moon (Naive Model).

Response group 11, 2% of 6th-grade and 2% of 10th-grade students, believed that the Earth's rotation, revolution, and Moon's revolution result in the phases of the Moon (Naive Model).

Response group 12, 2% of 6th-grade and 2% of 10th-grade students, credited the phases of the Moon to the different amounts of light reflected by the Earth (Naive Model).

Response group 13, 2% of 10th-grade students, believed that changes in relative distances of the Sun and the Moon cause the different phases of the Moon (Naive Model).

Response group 14 includes 2% of 8th-grade students who believed that the changes in weather cause the different phases of the Moon (Naive Model).

Response group 15, 2% of 6th-grade students reasoned that changes in the Earth and the Sun cause the different phases of the Moon (Naive Model).

Response group 16, 2% of 6th-grade students, believed that the phases of the Moon are due to the Earth's rotation and revolution (Naive Model). A portion of the interview with one student (sixth grade) in response group 16 who claimed that the Earth's rotation and revolution cause the phases of the Moon (R: Researcher S: Student) follows:
R: Do the phases of the Moon seem to change at night?
S: Yes.
R: Can you show me what phases of the Moon you see?
S: (hesitating).
R: I mean, What phases of the Moon do you see?
S: From a full Moon to a half Moon.
R: Why do you think that the phases of the Moon seem to change?
S: (hesitating).
R: Can you explain this using a diagram?
S: (drawing a diagram with the Earth revolving around the Sun and the Moon revolving around both the Earth and the Sun).
R: (pointing to the diagram) Where is the Sun?
S: Here.
R: (pointing to the diagram) If the Moon stays here, what kind of phase does the Moon have?
S: I am not sure. A full Moon.
R: Where is the observer?
S: Here
R: Why do you think that the phases of the Moon seem to change at night?
S: The Earth rotates and revolves around the Sun.
R: The Earth rotates and revolves around the Sun?
S: Yes
R: Are you sure?
S: I am not sure.
Transcripts of the interview indicate that the student tends to understand the Earth's motion in relation to the Sun, but does not have a clear picture as to the Moon's motion and why the phases of the Moon seem to change.

Response group 17, 2% of 6th-grade students, responded that the Earth and the Sun provide the Moon with light and energy (Naive Model).

Response group 18 includes 6% of 6th-grade, 17% of 8th-grade, and 16% of 10th-grade students who did not provide any responses to this question ("No" Model).

4. 4. 4 Summary

Unlike questions on gravity (I), (II), and the day/night cycle, a smaller percentage of the students at all three Grade Levels and at all three Achievement Levels holds the Scientific Model, while a higher percentage of the students holds a Naive Model for the phases of the Moon. The one exception is in the eighth grade, where a slightly higher proportion of the 8th-grade students hold the Scientific Model than a Naive Model.

The incidence of these Models did not show a linear trend related to Grade Level and Achievement Level for this question. Chi-square analysis showed an overall statistically significant pattern across Grade Level within Model Levels, while it did not show an overall statistically significant pattern across Achievement Level with Model Levels.

The reasons given related to Naive Models are classified as
follows: 1) motion of the Earth; 2) motion of the Moon; 3) combined motion of the Earth and Moon; 4) relative position of the Earth, Moon and Sun; 5) obstruction/shadows (related to eclipse); 5) differential reflective properties of the Moon and Sun; 6) changes in weather; and 7) relative distance of the Sun and Moon.

It is interesting that the 10th-grade students use unsound scientific terms regarding the motion of solar system to explain their answers. Students were often unable to explain or justify their answers.

4. 5 Change in Seasons

Question: We have summer, autumn, winter, and spring. What causes the change in seasons? You can explain the answer to this question using diagrams and words.

4. 5. 1 How are Korean 6th-, 8th-, and 10th-grade Students' Conceptions about the Change in Seasons Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the change in seasons question for Grade Level classified by Model is shown in Figure 9.

The Scientific Model for the change in seasons is that the Earth's axis tilts. The Naive Model category includes those student responses that are inconsistent with scientific theory, and the "No" Models are used for cases in which students did not provide any responses to this question.
Figure 9 and Table 19 show that a greater frequency at all Grade Levels holds Naive Model as compared to "No" Model and Scientific Model. Specifically, 88% of the 6th-grade students, 91% of the 8th-grade students, and 63% of the 10th-grade students hold Naive Models. None of the 6th-grade students, 2% of the 8th-grade students, and 29% of the 10th-grade students hold the Scientific Model. The 10th-grade students (29%) had a significantly greater (p<0.01) tendency toward Scientific Model than the other grades (0-2%). The 6th-grade students (88%) and the 8th-grade students (91%) had a significantly greater (p<0.01) tendency toward Naive Models than the 10th-grade students (63%). The frequency of Scientific Model increases with Grade Level; however, the incidence of Naive Model did not show a linear trend related to Grade Level. The 6th-grade students tended not to offer any answer at all rather than a Naive Model. For this question, the chi-square analysis did
show a statistically significant overall pattern ($\chi^2=28.94$, $p= .00001$).

Table 19
Contingency Tables Comparing Models with Each Grade Level for the Change in Seasons

<table>
<thead>
<tr>
<th></th>
<th>&quot;No&quot;</th>
<th>Naive</th>
<th>Scientific</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th grade (n=49)</td>
<td>12%</td>
<td>88%</td>
<td>0%</td>
</tr>
<tr>
<td>8th grade (n=53)</td>
<td>8%</td>
<td>91%</td>
<td>2%</td>
</tr>
<tr>
<td>10th grade (n=49)</td>
<td>8%</td>
<td>63%</td>
<td>29%</td>
</tr>
</tbody>
</table>

$x^2=28.94$, $p= .00001$

4. 5. 2 How are Korean High, Average, and Low Achievement Students' Conceptions about the Change in Seasons Distributed across the Scientific, Naive, and "No" Model Categories?

A bar graph comparison of the percentage of student responses to the change in seasons question classified by Achievement Level according to Model is shown in Figure 10. The categories of Scientific Model, Naive Model, and "No" Model for this question were used the same way in this section as in section 4. 5. 1.
Figure 10 and Table 20 show that for all Achievement Levels, Naive Model predominates: the low Achievement Level (77%); the average Achievement Level (84%); and the high Achievement Level (81%). There are slight differences between the Achievement Levels in the percentages using Scientific Model (8% of low, 6% of average, 17% of high achievement group). The incidence of these Models did not show a linear trend related to Achievement Level. For this question, the chi-square analysis did not show a statistically significant overall pattern ($\chi^2=8.25$, $p=.08255$).
Table 20

Contingency Table Comparing Models with Each Achievement Level for the Change in Seasons

<table>
<thead>
<tr>
<th>Achievement Level</th>
<th>&quot;No&quot; Model</th>
<th>Naive Model</th>
<th>Scientific Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>low achievement</td>
<td>15%</td>
<td>77%</td>
<td>8%</td>
</tr>
<tr>
<td>(n=52)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average achievement</td>
<td>10%</td>
<td>84%</td>
<td>6%</td>
</tr>
<tr>
<td>(n=51)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high achievement</td>
<td>2%</td>
<td>81%</td>
<td>17%</td>
</tr>
<tr>
<td>(n=48)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\chi^2 = 8.25, p = .08255
\]

4.5.3 What are Korean 6th-, 8th-, and 10th-grade Students' Naive Theories (Models) about the Change in Seasons?

Percentages of 6th-, 8th-, and 10th-grade student responses to the question about the change in seasons are shown in Table 21. Student responses were categorized into 11 response groups. The student responses were presented in order from the most frequent response group down to the least frequent group except for the "No" Model. When frequencies of a response group are equal, the group with more upper Grade Level student responses is given first.
Table 21  
Percentages of Student Responses to the Question about the Change in Seasons by Grade

<table>
<thead>
<tr>
<th>Response Group</th>
<th>Grade</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>1. The Earth's axis tilts</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>2. The Earth revolves</td>
<td>21</td>
<td>72</td>
</tr>
<tr>
<td>3. The relative distance between the Sun and the Earth</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>4. The relative difference in solar radiation</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>5. The Earth rotates</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>6. The location of the Earth with respect to the Sun</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>7. The place where sunlight falls on the Earth</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8. The relative difference in daytime</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>9. The Sun moves</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10. Different air pressure</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>11. I don't know</td>
<td>12</td>
<td>7</td>
</tr>
</tbody>
</table>

*: Scientific Model  **: Naive Model  ***: "No" Model

Response group 1 includes 2% of 8th-grade and 29% of 10th-grade students who responded correctly, indicating that the change in seasons is due to the tilt of the Earth's axis (Scientific Model).

Response group 2 includes 21% of 6th-grade, 72% of 8th-grade, and 41% of 10th-grade students who believed that the change in seasons is caused by the Earth's revolution (Naive Model). A portion of the interview with one student (tenth grade) in response group 2...
who claimed that the change in seasons is caused by the Earth's revolution (R: Researcher  S: Student) follows:

R: What causes the change in seasons?
S: The Earth revolves around the Sun.
R: Why do you think so?
S: The Earth revolves around the Sun.
R: The Earth revolves around the Sun?
S: Yes.
R: Can you show me that?
S: (The student did not respond).

Transcripts of the interview indicate that the student perceived that the Earth's revolution would result in the change in seasons but did not provide justification.

Response group 3 includes 23% of the 6th-grade, 13% of the 8th-grade, and 12% of the 10th-grade students who believed that the relative distance between the Sun and the Earth causes the change in seasons; that is, if the Earth is closer to the Sun, it is hotter and it is summer, and if the Earth is farther from the Sun, it is cooler and it is winter (Naive Model). A portion of the interview with one student (tenth grade) in response group 3 who claimed that the relative distance between the Sun and the Earth causes the change in seasons (R: Researcher  S: Student) follows:

R: What kinds of seasons do we have?
S: Spring, summer, autumn, and winter.
R: What season is it?
S: Summer.
R: Summer. Is summer hot?
S: Yes.
R: How about winter?
S: It is very cold.
R: What causes the change in seasons?
S: The Earth revolves once a year around the Sun. The Earth revolves in a circular orbit. If the Earth is closer to the Sun, it is hot. That is summer. If the Earth is farther from the Sun, the Earth is cold. That is winter.
R: You mean that when the Earth is closer to the Sun, the Earth receives more heat, and when the Earth is farther from the Sun, the Earth receives less heat?
S: Yes. I am not sure.
R: Where did you learn first about this?
S: From reference books and textbooks.

Transcripts of the interview indicate that the student perceived that the relative distance between the Sun and the Earth would result in the change in seasons. The student apparently learns this from reference books and textbooks.

Response group 4, 16% of 6th-grade and 8% of 10th-grade students, stated that the change in seasons is due to the relative difference in solar radiation; that is, solar radiation is stronger in summer and weaker in winter (Naive Model). A portion of the
interview with one student (sixth grade) in response group 4 who claimed that the change in seasons is due to the relative difference in solar radiation (R: Researcher S: Student) follows:

R: We have four seasons; spring, summer, autumn, and winter.
R: What season is it?
S: Summer.
R: After summer?
S: Autumn.
R: What causes the change in seasons?
S: I think that it is the difference in the amounts of solar radiation.
   In summer, the Earth receives the largest amount of solar radiation. In winter, it receives the smallest amount of solar radiation.
R: What about autumn and spring?
S: The amounts of solar radiation are not less or greater. Just in between.
R: Can you explain this using a diagram?
S: (drawing a diagram) In summer, the Earth receives the largest amount of solar radiation. In winter, it receives the smallest amount of solar radiation.
R: You mean that the change in seasons results from the difference in the amount of solar radiation.
S: Yes.
R: Where did you learn first about this?
S: From science textbooks.
Transcripts of the interview indicate that the student perceived that the relative difference in solar radiation would result in the change in seasons. The student apparently learns this from science textbooks.

Response group 5 containing 8% of 6th-grade and 4% of 8th-grade students, reasoned that the Earth's rotation causes the change in seasons (Naive Model). A portion of the interview with one student (sixth grade) in response group 5 who claimed that the Earth's rotation causes the change in seasons (R: Researcher S: Student) follows:

R: What season is it?
S: Summer.
R: After summer.
S: Autumn.
R: What causes the change in seasons?
S: The Earth's rotation.
R: The Earth's rotation? Can you explain this using a diagram.
S: (drawing a diagram). Here is the Sun. (hesitating)
R: How does the Earth's rotation cause the change in seasons?
S: I am not sure.

Transcripts of the interview indicate that the student perceived that the Earth's rotation would result in the change in seasons. No justification for this was provided by the student.

Response group 6 includes 10% of 6th-grade students who believed that the change in seasons is due to the location of the
the North Pole of the Sun, it is cool and therefore it is winter, and when the Earth moves toward the South Pole of the Sun, it is hot and therefore it is summer (Naive Model).

Response group 7 includes 6% of 6th-grade students who responded that the change in seasons depends on the place where sunlight falls on the Earth; that is, when sunlight falls on the front of the Earth, it is hot and therefore it is summer, and when sunlight falls on the back of the Earth, it is cool, and therefore it is winter (Naive Model).

Response group 8, consisting of 2% of 6th-grade and 2% of 10th-grade students, believed that the change in seasons is due to the relative difference in daytime, stating that in summer daytime is longer and so it is hotter in summer, and in winter daytime is shorter and so it is cooler in winter (Naive Model).

Response group 9 includes 2% of 8th-grade students who indicated that the change in seasons is due to the Sun's movement (Naive Model).

Response group 10, 2% of 6th-grade students, explained that the change in seasons is due to air pressure difference (low pressure in summer and high pressure in winter (Naive Model).

Response group 11 includes 12% of 6th-grade, 7% of 8th-grade, and 8% of 10th-grade students who did not provide any responses to this question ("No" Model).
4. 5. 4 Summary

Unlike questions on the gravity (I), (II), and the day/night cycle, a smaller percentage of the students at all three Grade Levels and at all three Achievement Levels holds the Scientific Model, while a higher percentage of the students holds a Naive Model for the change in seasons.

The incidence of these Models did not show a linear trend related to Grade Level and Achievement Level for this question. Chi-square analysis showed an overall statistically significant pattern across Grade Level within Model Levels, while it did not show an overall statistically significant pattern across Achievement Level within Model Levels.

The reasons given related to Naive Models are classified as follows: 1) distance between the Sun and Earth; 2) relative difference in solar radiation; 3) motion of the Earth; 4) location of the Earth with respect to the Sun; 5) place where sunlight falls on the Earth; 6) relative difference in daytime; and 7) different air pressure.

Many 8th-(72%) and 10th-grade students (41%) relate the change in seasons to the Earth's revolution, while many 6th-grade students (23%) relate the change in seasons to the relative distance between the Sun and the Earth.

4. 6 Overall Summary of Findings

Overall summary of Grade Level and Achievement Level differences by Model are shown in Table 22. The following trends
are revealed from the findings in sections 4.1 through 4.5.4 and Table 22.

1. Students at all three Grade Levels and all three Achievement Levels tend to hold Scientific Models and not Naive Models related to gravity (I) and (II) and the day/night cycle questions.

2. For the questions on the phases of the Moon and change in seasons, more students at each Grade Level and each Achievement Level hold Naive Models and not Scientific Models except for the eighth grade, where slightly more hold Scientific Models and not Naive Models.

3. The distribution of Models by Grade Level is very similar to the distribution of Models by Achievement Level.

4. For gravity (II), the day/night cycle, and the change in seasons questions, the 10th-grade students have a significantly greater tendency toward the Scientific Models than do the 6th grade students.

5. For gravity (I), (II), and the phases of the Moon questions, the 8th-grade students have a significantly greater tendency toward the Scientific Models than do the 6th-grade students.

6. For the day/night cycle, and the change in seasons questions, the 10th-grade students have a significantly greater tendency toward the Scientific Models than do the 8th-grade students.
7. For gravity (II), day/night cycle, the phases of the Moon, and the change in seasons questions, the 6th-grade students have a significantly greater tendency toward Naive Models than do the 10th-grade students.

8. For gravity (I), (II), and the phases of the Moon questions, the 6th-grade students have a significantly greater tendency toward Naive Models than do the 8th-grade students.

9. For the change in seasons question, the 8th-grade students have a significantly greater tendency toward Naive Models than do the 10th-grade students.

10. For gravity (II), and the day/night cycle questions, the high achievement students have a significantly greater tendency toward the Scientific Models than do the low achievement students.

11. For gravity (II), and the day/night cycle questions, the average achievement students have a significantly greater tendency toward the Scientific Model than do the low achievement students.

12. For gravity (II), and the day/night cycle questions, the low achievement students have a significantly greater tendency toward Naive Models than do the high achievement students.

13. For the day/night cycle question, the low achievement students have a significantly greater tendency toward Naive Models than do the average achievement students.
14. For the phases of the Moon question, the average achievement students have a significantly greater tendency toward Naive Models than do the high achievement students.

15. For gravity (II) question, the low achievement students have a significantly greater tendency toward "No" Models than do the high achievement students.

16. The difference of proportions of Scientific, Naive, and "No" Model classifications are more numerous between Grade Levels than between Achievement Levels.
### Table 22
Summary of Grade Level and Achievement Level Differences by Model

<table>
<thead>
<tr>
<th>Topic</th>
<th>&quot;No&quot; Model</th>
<th>Naive Model</th>
<th>Scientific Model</th>
<th>Overall ($x^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity (I)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Level</td>
<td>6 &gt; 8**</td>
<td>8 &gt; 6*</td>
<td></td>
<td>9.16</td>
</tr>
<tr>
<td>Achievement</td>
<td></td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
<tr>
<td>Gravity (II)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Level</td>
<td>6 &gt; 8**</td>
<td>10 &gt; 6**</td>
<td>10 &gt; 6**</td>
<td>28.34**</td>
</tr>
<tr>
<td>Achievement</td>
<td>L &gt; H*</td>
<td>H &gt; L**</td>
<td>A &gt; L**</td>
<td></td>
</tr>
<tr>
<td>Day/night cycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Level</td>
<td>6 &gt; 10**</td>
<td>10 &gt; 6**</td>
<td>10 &gt; 8*</td>
<td>11.22*</td>
</tr>
<tr>
<td>Achievement</td>
<td>L &gt; H*</td>
<td>H &gt; L**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phases of the Moon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Level</td>
<td>6 &gt; 8**</td>
<td>8 &gt; 6**</td>
<td></td>
<td>12.24*</td>
</tr>
<tr>
<td>Change in seasons</td>
<td></td>
<td></td>
<td></td>
<td>3.57</td>
</tr>
<tr>
<td>Grade Level</td>
<td>6 &gt; 10**</td>
<td>10 &gt; 6**</td>
<td></td>
<td>28.94**</td>
</tr>
<tr>
<td>Achievement</td>
<td>A &gt; H*</td>
<td>H &gt; L**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6, 8, 10: 6th, 8th, 10th-Grade Level  
L, A, H: Low, Average, High Achievement Level  
*: p< 0.05  **: p< 0.01

4. 7 Research Question 4  
To what Sources do Korean Students attribute Naive Theories (Models) about Selected Natural Phenomena in Earth Science?  

The subjects used for identifying the possible sources of Naive theories (Models) were 15 students who had responses to both the INTTES and the interview.  

Identification of possible sources of naive theories comes from student responses to the Identification of Naive Theories Test in Earth Science (INTTES) and from interviews. In the INTTES and during the interview, the students were asked to indicate their
sources of knowledge (Where did you first learn about this?). After identifying the students' naive theories, their sources of knowledge were categorized as everyday experience, teachers, textbooks, instructional/general television programs, and other books as suggested by Ivowi and Oludotun (1987).

One Korean graduate student reviewed the categorizations which were categorized by the researcher. There was 100% agreement between the researcher and the graduate student for the categorizations.

The sources of naive theories as identified by the students are shown in Appendix E. The Appendix E shows that for the question on the gravity (I) and the gravity (II) the sources of naive theories identified by the students are personal experience (A) and teachers (B). For the question on the day/night cycle, the source of naive theories identified by the students is teachers (B). For the questions on the phases of the Moon and the change in seasons, the prevalent sources of naive theories identified by the students are teachers (B) followed by textbooks (C) and personal experiences (A). In summary, the most frequently cited sources across all the questions are teachers.

4. 8 Research Question 5
How do Student Responses to the Open-Ended Written Question (INTTES) Format Compare to the Responses to an Interview Format for Identifying Students' Naive Theories?

One of purposes of the interviews in this study was to
investigate students' naive theories which might be overlooked by the Identification of Naive Theories Test in Earth Science (INTTES) and to validate the INTTES.

The subjects used for comparing the student responses to the INTTES and to the interview were 15 students who had responses to both the INTTES and the interview. Key phrases within student responses to the INTTES and the interview were identified and compared. A comparison of INTTES and the interview is shown in Appendix F. Appendix F shows 93% agreement between the INTTES and the interview.

4.9 Discussion

4.9.1 Common Student Conceptions

Students may develop their own theories, based on their direct experiences and observations. In this study, the students' conceptions of gravity (I), (II), the day/night cycle, the phases of the Moon, and the change in seasons vary greatly. There are two general types of naive theory responses to gravity (I) and (II) questions: 1) correct results combined with incorrect reasons; and 2) incorrect results combined with incorrect reasons. The incorrect reasons are classified as related to: 1) the effects of air/no air/air pressure on gravity; 2) the effects of temperature on gravity; 3) the effects of shape of the Earth on gravity; 4) the effects of the movement of the Earth on gravity; 5) the effects of a cap on a bottle on gravity.

For the day/night cycle, the phases of the Moon, and the change in seasons, responses consist of correct reasons and incorrect
reasons. Regarding the day/night cycle question, students list motion of the Earth, motion of the Sun, sources of light, and relative motion of the Earth, Moon, and Sun as incorrect reasons.

Regarding the phases of the Moon question, students list motion of the Earth, motion of the Moon, combined motion of the Earth and Moon, obstruction/shadows (related to eclipse), differential reflective properties of the Moon and Sun; changes in weather, and relative distance of the Sun and Moon as incorrect reasons.

Lastly, regarding the change in seasons question, students list relative distance of the Sun and Earth, relative difference in solar radiation, motion of the Earth, location of the Earth with respect to the Sun, place where sunlight falls on the Earth, relative difference in daytime, and different air pressure as incorrect reasons.

4. 9. 2 Unsound Scientific Terms

Older students (tenth and eighth grade) know more than younger students (sixth grade), but they tend to use their knowledge about selected natural phenomena in earth science in a way that is inconsistent with scientific principles and theories. This tendency is seen on questions on the phases of the Moon and the change in seasons. For the question on the change in seasons, 72% of eighth grade and 41% of tenth grade believed that the change in seasons is caused by the Earth's revolution. This tends to support the findings of Cosgrove and Osborne (1983), and Kook (1988) that many older students use unsound scientific terms to explain their answers.
This finding is supported by Kim (1989), who stated that the higher the grade and ability level, the more sophisticated are students' notions. These notions are not always clearly understood and are applied in the explanation of a phenomena in an incomplete and naive way.

4. 9. 3 Conceptual Complexity

Students hold many more naive theories for questions on the phases of the Moon and the change in seasons than for those questions on gravity (I) and (II), and the day/night cycle. It is known that even college students have difficulty in understanding these topics. As mentioned in Chapter I, a filmmaker asked a group of Harvard University graduates to explain the change in seasons, and all students except two used the naive theories that the change in seasons is due to the relative distance between the Sun and the Earth. Also, Kueth (1963) supports this by declaring that 70% of college level students have naive theories of the phases of the Moon. One possible explanation for these findings is that the phases of the Moon and the change in seasons are more abstract and complex than gravity (I) and (II), and the day/night cycle.

4. 9. 4 Consistency of Naïve Theories

For the question on gravity (II) and the question on the day/night cycle, there is a progressive increase in the percentage of students using Scientific Models as Grade Level and Achievement Level increase. There is also a corresponding decrease in the proportion of students holding Naïve Models as Grade Level and
Achievement Level increase. However, for the question on the phases of the Moon, the question on gravity (I), and the question on the change in seasons, there is no linear trend in the number of students having Naive Models and Scientific Models as Grade Level and Achievement Level increase. Though naive theories decrease for each specific concept, as students get older, have more science instruction, or reach higher achievement levels, naive theories persist even among high school students. These findings are in agreement with Champagne and Klopfer (1983), who stated that naive theories show remarkable consistency across diverse populations regardless of age (grade) and ability.

4. 9. 5 Sources of Naive theories (Models)

   For the questions on the phases of the Moon and the change in seasons, the most common source of naive theories identified by students is teachers, followed by textbooks and personal experience. Sadler (1987) supports these findings in a study on students' naive theories in astronomy, indicating that students overwhelmingly attribute their sources to their schooling (teachers and textbooks). Also, Cho, Kahle, and Nordland (1985) indicate that textbooks may be sources of naive theories.

   There is some question as to how perceptive students are in attributing cause or first-source to naive theories. For the questions on gravity (I) and (II), and the day/night cycle, the number of students holding naive theories was too small to suggest any tendencies or trends. However, some sources of naive theories for
those questions may be the students' everyday experience and observations. For example, identification of "down" in relation to the bottom of a page of paper and the explanation of the day/night cycle as a result of the Sun's movement most likely result from everyday experiences and observations. These findings are supported by Champagne and Klopfer (1983) who stated that naive theories come from the students' everyday experiences and observations.

4. 9. 6 Grade Level Differences

The overall summary of findings in section 4. 6 indicates that the 10th-grade students have a greater tendency toward Scientific Model than the 6th-grade students. For gravity (II) and the phases of the Moon, the 8th and 10th-grade students were similar in that they more often held the Scientific Model than did the 6th-grade students. For the day/night cycle and change in seasons, the 6th and 8th-grade students were similar in that they more often held Naive Models than did the 10th-grade students.

One possible explanation for these Grade Level differences is that the 10th-grade students are older, have more instruction, and have spent much more time on these topics. The upper grade level students are also more likely to be at the formal reasoning levels of Piaget's stages. This tends to be consistent with the findings of Cosgrove and Osborne (1983) that older students more often hold the Scientific Model than younger students for certain concepts.
4. 9. 7 Achievement Level Difference

The overall summary of findings in section 4. 6 indicates that the high achievement students have a significantly greater tendency toward the Scientific Models than the low achievement students, while the high achievement students have significantly less tendency toward Naive Models than the low achievement students. Head (1986) indicates that students with higher Achievement Level at all Grade Levels may be more capable of formal and abstract thinking which would allow them to comprehend and adopt scientific explanations of natural phenomena.

However, for the questions on gravity (I), the phases of the Moon, and the change in seasons there is no difference between Achievement Levels. These findings are consistent with Champagne and Klopfer (1983), who stated that naive theories show remarkable consistency across diverse populations regardless of ability.

4. 9. 8 A Comparison of Student Responses to the INTTES and to the Interview.

Each of the 15 students were asked to respond to 5 items in both the written and interview format. This made a total of 75 responses to be classified as Scientific Model, Naive Model, or "No" Model. Of these 75 classifications four responses, based upon the written format, are different from those made using the interview format. This represents a 93% agreement. Two Scientific Model responses from the written were classified as Naive Model using the interview data and two Naive Model responses from the written
were classified as Scientific using the interview data. This is consistent with the findings of Bar (1987) and Bar and Travis (1991), in that open-ended written questions elicit similar responses to those from interviews. This is also supported by Seddon and Pedrosa (1988) who found no significant differences between the explanations given by spoken and written methods of questioning in a comparison of first year university students in chemistry.

4. 9. 9 Naive Theories of Students with Historical Views

Two percent of 6th-grade and 2% of 8th-grade students believe that the day/night cycle is due to the Sun's movement. That is, the fact that the Sun rises in the morning and sets in the evening results in the day/night cycle. This is the geocentric, Ptolemaic view which is that the Sun moves around the Earth. This is supported by Wandersee (1985) who believes that there is a parallel between the history of science and the development of students' scientific concepts.

On gravity (I) question, one 6th-grade student indicated that the rock would fall downward and that the student learned it from her experience (when I drop an eraser, it falls down). The student may believe that the Earth is flat, which was the prevailing belief until 1522 year. This was the year in which Magellan completed the first trip all the way around the Earth. This finding is consistent with Mali and Howe (1979) who find that Nepali children believe that the Earth is flat. This is supported by Vosniadou (1989) who find
that American students believe that things fall in a downward direction rather than toward the center of the Earth. This is also supported by Vosniadou and Brewer (1989) who find that American students believe that the Earth has an edge and that things fall down from that edge.

4. 9. 10 Temperature Related to Gravity

On gravity (II) question, 14% of 6th-grade students, 4% of 8th-grade students, and 4% of 10th-grade students indicated that temperature (freezing) would affect gravity, by reasoning that the water in the bottles would be frozen at the South Pole and that the bottom of the bottles would be toward the center of the Earth. This is consistent with the finding of Treagust and Smith (1989), in that some individuals believe that the surface temperature of a planet affects its gravity.

4. 9. 11 Comparison of Western Studies

A comparison of the present study and the Western studies is shown in Table 23. Table 23 shows that many Western students hold Naive Models for the phases of the Moon and the change in seasons, while many Western students hold the Scientific Model for gravity and the day/night cycle. These findings are very similar to the present study. Overall it appears that for gravity, the day/night cycle, the phases of the Moon, and the change in seasons questions, Korean 6th-, 8th-, and 10th-grade students hold Naive Models less often than Western 5th-, 8th-, and 11th-grade students in the Schoon's (1989) sample.
The item differences between Schoon's sample and the Korean sample are as follows:

1. For the day/night cycle question American students have a greater tendency toward Naive Models than Korean students at all grade Levels.

2. For the phases of the Moon question American students have a greater tendency toward Naive Models than Korean students at senior high school level.

3. For the change in seasons question American students have a greater tendency toward Naive Models than Korean students at secondary school level.

It seems that grade level and schooling more closely relate to the reduced frequency of Naive Model incidence in Korean students when compared to American students.
Table 23

Comparison of Korean Students' Naive Models to Western Students' Naive Models

<table>
<thead>
<tr>
<th>Topic</th>
<th>Vosniadou and Brewer (1989)</th>
<th>Schoon (1989)</th>
<th>This study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5th</td>
<td>5th 8th 11th 6th 8th 10th</td>
<td></td>
</tr>
<tr>
<td>Gravity</td>
<td>45% - - -</td>
<td>33%* 7%* 9%*</td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>- 49% 29% 33% 18% 11% 2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moon</td>
<td>- 66% 55% 65% 69% 36% 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seasons</td>
<td>- 91% 92% 84% 88% 91% 63%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*: percentage combined by gravity (I) and gravity (II)
-: topics not related to among studies
CHAPTER V
CONCLUSIONS

This chapter presents conclusions of this study. It is divided into five sections: 1) overview; 2) research questions; 3) answering the research questions; 4) implications; and 5) recommendations for future study.

5.1 Overview

Students tend to develop theories about natural phenomena based on their direct experience and observations. These theories can often cause difficulties when students apply what they have learned to predict and describe natural phenomena. Champagne and Klopfer (1983) suggest that the failure of these students is related to the persistence of naive theories brought with them to science classes.

The fact that the learner develops a world view acquired through everyday experiences is consistent with a constructivist view of science teaching and learning. In the constructivist view, knowledge is constructed in the mind of the learner; that is, the learner attempts to make sense of his/her world using previously acquired knowledge through everyday experiences.

Naive theories are persistent even when students are exposed to traditional instructional methods because naive theories are deeply rooted in the learner's direct experiences.
The main purposes of this study were: 1) to determine differences in Korean students' conceptions about selected natural phenomena in earth science as related to Grade Level; 2) to identify how Korean students' conceptions about selected natural phenomena in earth science are related to science achievement; 3) to identify and describe naive theories that Korean 6th-, 8th-, and 10th-grade students hold about selected natural phenomena in earth science; 4) to explore the sources of naive theories about selected natural phenomena in earth science; 5) to compare student responses to an open-ended written question format (INTTES) with those from an interview.

Many recent studies have explored naive theories about natural phenomena held by students in the United States, Australia, and some European countries. A few studies have investigated Korean students' naive theories. To date, none of the Korean studies have investigated naive theories related to gravity, the day/night cycle, the phases of the Moon, and the change in seasons. These topics have been studied by Western researchers using elementary, middle school, and senior high students.

There are three research traditions for identifying students' naive theories: 1) interviews; 2) multiple choice tests; and 3) open-ended written questions. Taking the average Korean class size (45-60) and the methods used for eliciting the variety of unique responses held by students into consideration, an open-ended written question instrument, called Identification of Naive Theories Test in Earth Science (INTTES) was selected for this study. The
INTTES included 5 items: two items on gravity; one on the
day/night cycle; one on the phases of the Moon; and one on the
change in seasons. Interviews were used to investigate students'
naive theories which might be overlooked by the INTTES, to validate
the INTTES, and to identify the sources of naive theories as
perceived by students.

Subjects for this study included 151 Korean students: 49
grade 6 (24 boys and 25 girls) students in one class from one
elementary school; 53 grade 8 students in one class from one junior
high school; 49 grade 10 students in one class from one senior high
school.

5.2 Research Questions

The research questions of this study are as followings.
1) How are Korean 6th-, 8th-, and 10th-grade students'
conceptions about selected natural phenomena in earth science
distributed across the Scientific, Naive, and "No" Model
categories?
2) How are Korean high, average, and low achievement students'
conceptions about selected natural phenomena in earth science
distributed across the Scientific, Naive, and "No" Model
categories?
3) What are Korean 6th-, 8th-, and 10th-grade students' naive
theories about selected natural phenomena in earth science?
4) To what sources do Korean students attribute naive
theories (Models) about selected natural phenomena in earth
How do student responses to an open-ended written question format (INTTES) compare to the responses to an interview format for identifying students' naive theories?

5. 3 Answer the Research Questions

1a. For questions on gravity (I) and (II), and the day/night cycle, a majority of the students at all three Grade Levels hold a Scientific Model.

1b. For questions on the phases of the Moon and the change in seasons, a higher percentage of the students holds Naive Models.

1c. There is generally a progressive increase in the percentage of students using Scientific Models as Grade Level increases.

2a. For questions on gravity (I) and (II), and the day/night cycle, a majority of the students at all three Achievement Levels holds a Scientific Model.

2b. For questions on the phases of the Moon and the change in seasons, a higher percentage of students holds Naive Models.

2c. There is generally a progressive increase in the percentage of the students holding a Scientific Model as Achievement Level increases.

3. There are many naive theories about the earth science phenomena in this study. These naive theories involve confusion related to the shape and movement of the Earth, influence of air/no air/air pressure, influence of cap,
influence of phases of matter, influence of temperature, movement of the Earth, Sun, and Moon, sources of light, influence of obstruction and shadows, differential reflective properties of the Moon and Sun, change in weather, relative distance of the Sun and Moon, relative distance of the Sun and Earth, relative difference in solar radiation, location of the Earth with respect to the Sun, place where sunlight falls on the Earth, relative difference in daytime, and different air pressure.

4. For the questions on the phases of the Moon and the change in seasons, students list their teachers most frequently as the sources of their naive theories. Textbooks and personal experience are next most frequently cited sources.

5. A comparison of the open-ended written question format (INTTES) and the interview format shows 93% agreement.

5. 4 Implications

The findings generated in this study raise some important issues for both teachers and science curriculum developers.

5. 4. 1 Teachers

Results for this study indicate that a small percentage of students held naive theories on questions on gravity and the day/night cycle. More than half of the students held naive theories on questions related to the phases of the Moon and the change in seasons. Teachers should know that these findings are consistent
with the constructivist view that knowledge is constructed in the
mind of the learner on the basis of preexisting cognitive structures
or schemes. Teachers should think about possible methods to
evaluate student conceptions of natural phenomena before
instruction begins. The open-ended written questions used in this
study seem to be suitable for use in large classrooms and for
eliciting the variety of unique responses held by students.

Also, teachers should keep in mind that many students having
naive theories of the phases of the Moon and the change in seasons
attribute their sources of knowledge to teachers.

Finally teachers should develop teaching strategies to
overcome students' naive theories. Osborne (1980) suggests that
teachers use activities which provide students with challenges and
encouragement to rethink their ideas, to elaborate these ideas, and
to change their ideas. Also, Nussbaum and Novick (1982) suggest
that the first step in an instructional strategy to overcome
students' naive theories should be making the students aware of
their own conceptions. For example, for the gravity (I) question, 2%
of 6th-grade students indicated that there is no air to pull a rock
down. A suitable activity which might move students toward a
Scientific Model is the "coin and feather" demonstration. A glass
tube is evacuated using a vacuum pump and then a feather and a coin
are dropped simultaneously. It is seen that "coin and feather" fall at
the same rate and reach the bottom at the same time. This
demonstrates that objects fall at the same rate and that gravity
acts in a constant manner on objects whenever there is no air around
them. Six percent of 10th-grade students indicated that the Earth's rotation would affect gravity, by believing that the rock would fall at an angle toward the surface of the Earth (see response group 3 in Table 9). One possible experiment would be to place a student seated in a stationary bus and have the student drop a coin into a cup placed on the floor of the bus. The student would then be asked to drop the coin into the cup while the bus was moving at a constant velocity. The student would be able to note that the coin trajectory was the same in both instances, straight down. This experiment could help to illustrate to the student that gravity is not influenced by the Earth's rotation.

For the gravity (II) question, 2% of 6th-grade students indicated that the water in the bottles would remain or spill out depending upon the cap. The water in the closed bottle would remain and the water in the open bottle would empty from the bottle. One possible experiment would use be to use a paper-cup and a metal globe. The paper-cup would have a magnet attached to the bottom which would be attracted to the metal globe. The student could place some iron filings in the paper-cup and place it on the globe with the North Pole pointing up. The student could then move the paper-cup around the globe to the South Pole. The student would be able to see that the iron filings do not fall out of the paper-cup when moving from the North Pole to the South Pole. It would be important to explain that the Earth's attraction (gravity) for objects is not magnetic but has some similar characteristics.

As seen in Chapter IV, 2% of 6th-grade and 2% of 8th-grade
students had a geocentric, Ptolemaic view of the day/night cycle. As suggested by Wandersee (1985), if the teacher described the history of perspectives on the day/night cycle or if the teacher lets the students read the historical accounts of discovery, it could then be pointed out to the students that they hold a view similar to one which many people had in the past. The teacher could then outline or have students research the historical developments which took place from Ptolemaic theory to the correct heliocentric, Copernican theory of the day/night cycle. Special note and discussion should center on how this shift in scientific theory occurred. This is one possible way to move students from Naive Model to the Scientific Model.

For the phases of the Moon question, some of the student responses suggest a confusion between the phases of the Moon and the characteristics of a lunar eclipse. A possible way to move students from a Naive Model to the Scientific Model would be to use a working model of the Sun, Earth, and Moon with a light source and different sized balls to simulate the phases of the Moon and how that phenomena differs from that of an eclipse.

For the change in seasons question, 23% of 6th-, 13% of 8th-, and 12% of 10th-grade students indicated that the relative distance between the Sun and the Earth affects the change in seasons. A possible activity to change this Naive Model would be to have students graph the distance of the Earth to the Sun during different seasons using data from an almanac to help them discover another alternative explanation. Another general approach to move from Naive Models to the Scientific Model for this question is to chart the
length and angle of the shadow of a straight stick at the same location and same time of day over one year. The students would be able to see that the change in seasons is related to the length and angle of the shadow of the stick. This observation could be used to lead the students to identifying the tilt of the Earth in relation to the position of the Sun as an attractive model to explain the change in seasons.

As another general teaching strategy, Ausubel in *Educational Psychology* (1968) indicates that "If I had to reduce all of educational theory to just one principle, I would say this: the most important factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, 1968, p. iv). The findings of this study revealed what Korean students already know about selected natural phenomena in earth science. Korean teachers should determine what the students already know and/or believe and then design experiences in school to help them move from Naive Models toward Scientific Models. It might be valuable to engage students in activities designed to determine what evidence could be gathered to support or refute naive theories or perspectives related to science phenomena as opposed to presenting definitions and facts in a expository fashion.

5. 4. 2 Science Curriculum Developers

Textbooks are materials and resources from which students construct knowledge. Textbooks are considered as an important source in the construction of students' knowledge. This is
consistent with the findings of this study, that some students attributed the sources of their knowledge to textbooks. Cho, Kahle, and Nordland (1985) claim that textbooks may be a source of naive theories. In light of this, Korean science textbook publishers and curriculum developers should consider ways to overcome students' naive theories. Taking a close look at the sequences in Korean textbooks as seen in Table 3 of Chapter III, topics investigated in this study are not articulated across the elementary, junior, and high school levels. This topical, unconnected sequence may contribute to naive theories. In addition, the researcher suggests that in the elementary Korean science textbook (Integrated Science Textbook, 1988b), the day/night cycle concept in the 2nd grade, the phases of the Moon in the 5th grade, and changes in seasons concept in the 6th grade should be placed in one unit or at least connected systematically so that students have more opportunity to make direct comparisons and distinctions.

In a Korean senior high textbook (Separate Earth Science Textbook, 1988d, p. 174), the elliptical diagram of the Earth's orbit around the Sun, which is used to illustrate Kepler's second law, is possibly contributing to students' naive theories related to the change in seasons because the diagram depicts the distance between the Earth and Sun as variable. Korean curriculum developers should consider these kinds of naive theories and then make changes to attempt to move students from a Naive Model to a Scientific Model.

Another suggestion to textbook and curriculum developers is to include lists of common student naive theories along with
experiments, demonstrations, and readings which would help students move toward Scientific Models. These should be included in the teacher guides and teacher editions of textbooks for each topic.

5.5 Recommendation for Future Study

Recommendations for future research are:

1. This study is a part of a long-term research agenda including a) the documentation of the occurrence and the description of naive theories in Korean students, (b) the characterization of these naive theories, (c) recognition of potential sources of these naive theories, (d) the generation of instructional and curricular strategies for moving those with naive theories toward scientific theories, and (e) research to study the implementation and effects of these new strategies. Future study should focus on (d) and (e).

2. Investigations of teachers' theories should be conducted to see whether naive theories (Models) persist among science educators in the schools of Korea.

3. Determine naive theories which children have for other earth science topics (e.g., rock formation, mountain building, earthquake, geological time, and the water cycle).

4. Explore to what extent logical reasoning abilities account for the development of scientific theories or naive theories.

5. In future studies, the number of students interviewed should be increased and the types of questions modified to be more open-ended. More interviews would provide more opportunity
to identify the students' naive theories. A future study should make use of more open-ended questions in the interviews. For example in this study, the researcher asked questions such as "what is this?", while pointing to a diagram, which led the students to answer with single word responses. An open-ended question would ask "describe this picture". This would enable the students to have more freedom in their answers, thus providing a broader range of response.

6. Data should be collected at other grade levels to see if different naive theories are held by different grade levels. Also, urban and isolated rural populations might be sampled to see how the environment and different learning opportunities might relate.

7. Longitudinal studies should be conducted to see at what points significant changes from Naive to Scientific Models occur.

8. The format of the gravity (II) question should be changed. The gravity (II) question introduced a number of irrelevant distracting variables (e.g., temperature, passing the equator, traditional orientation of objects on the Earth's surface). Also, the gravity (II) question (19%) created more "No" Model responses than gravity (I) question (6%). It may be a result of students interpreting the question in some way that the researcher had not anticipated which resulted in a system which became too confusing and complicated for the students to deal with. One possible way to alter this question and eliminate some of the irrelevant variables is to use sand in the
bottles instead of water.

9. Research comparing public vs private schools and boys vs girls as to incidence of Naive Models should be conducted.

10. Comparison of U.S. textbooks and Korean textbooks should be made in terms of the incidence of content which might relate to the creation or elimination of Naive Models.
REFERENCES


APPENDIX A
IDENTIFICATION OF NAIVE THEORIES TEST IN EARTH SCIENCE (INTTES)
(ENGLISH)
Identification of Naive Theories Test in Earth Science
(INTTES)

Grade Level-------------------
Class-------------------------
Name-------------------------
1. In the following picture, a little girl stands on the Earth. This little girl has a rock in her hand and she is going to drop the rock. In which direction would the rock fall?

1) Draw a line showing the direction in which the rock would fall:

2) Explain your answer

3) Where did you first learn about this?
2. This picture shows two bottles on the North pole. One of them is closed and the other is opened. Both are half-filled with water. Suppose that a little girl takes the bottles to the South pole. What happens to the positions of the bottles and to the water in the bottles?

1) Draw a picture of the bottles at the South pole and tell what would happen to position of the bottles and to the water in the bottles:

2) Explain your answer

3) Where did you first learn about this?
3. It is dark at night and light during the day. What causes the day and night cycle? You can explain the answer to this question using diagrams and words.

2) Draw diagrams:

2) Explain your answer

3) Where did you first learn about this?
4. From one day to the next, the moon has the different phases. Why do the phases of the Moon seem to change? You can explain the answer to this question using diagrams and words.

1) Draw diagrams:

2) Explain your answer

3) Where did you first learn about this?
5. We have summer, autumn, winter, and spring. What causes the change in seasons? You can explain the answer to this question using diagrams and words.

1) Draw diagrams:

2) Explain your answer

3) Where did you first learn about this?
APPENDIX B
IDENTIFICATION OF NAIVE THEORIES TEST IN EARTH
SCIENCE(INTTES)
(KOREAN)
지구과학의 자연현상에 관한
나이브 시어리 조사

학교-----------------------------

학년------------ 반 ------------

이름-----------------------------
1. 다음 그림은 한 사람이 실제 지구위의 한 지점에서 서 있는 장면이다. 이 사람은 한 손에 돌을 들고 있는데 이 돌을 떨어뜨리라고 한다. 그 돌은 어느 쪽 방향으로 떨어질까?

![그림]

1) 돌이 떨어지는 방향을 그림위에 선으로 나타내어 보시오.

2) 왜 그렇게 떨어진다고 생각합니까? 그 이유를 설명하여 보시오?

3) 어디에서 이 사실을 처음 알게 되었습니까?
2. 다음 그림은 북극위에 반쯤 끌려 빗물로 채워진 두 물병이 놓여 있는 것을 나타내는 그림이다. 두 물병 중 한 물병은 마개로 닫혀 있고 다른 하나는 마개가 없다. 이 두 물병들을 남극위에 가져다 놓으면 어떤 위치와 어떤 상태로 놓여질까?

1) 그림 위에 두 물병의 위치와 물의 상태를 그려 보시오.

2) 왜 그렇다고 생각합니까? 그 이유를 설명하여 보시오.

3) 어디에서 이 사실을 처음 알게 되었습니까?
3. 우리는 날에 밤과 밤에 어둠이라는 사실을 알고 있다. GNOME 밤과 밤의 변화가 생각가? 그 이유를 그림을 그리고 설명하여 보시오.

1) 그림을 그리고 보시오.

2) 그 이유를 설명하여 보시오.

3) 어디에서 이 사실을 처음 알게 되었습니까?
4. 우리는 범마다 달의 다른 모습을 볼 수 있다. 왜 달은 범마다 다른 모습으로 보일까? 그 이유를 그림을 그려 설명하여 보시오.

1) 그림을 그려 보시오.

2) 그 이유를 설명하여 보시오.

3) 어디에서 이 사실을 처음 알게 되었습니까?
Task (Question) 1: draw a line showing that the rock would fall and explain students' reason

Materials: picture showing a person standing on the Earth

Q1: What does the circle represent?
Q2: Is the size of the person relative to the Earth reasonable?
Q3: In which direction would the rock fall?
Q4: Why? Would it fall that way?
Q5: Why do you think so?
Q6: Where did you first learn about this?

Task (Question) 2: draw a picture of the bottles at the South pole and explain students' reason

Material: picture showing two bottles which are half-filled with water standing on the Earth

Q1: What does the circle represent?
Q2: What does N and S mean?
Q3: Can you tell me what you know about the North and South pole.
Q4: What happens to the positions of the bottles and to the water in the bottles?
Q5: Why do you think so?
Q6: Where did you first learn about this?

Question 3: explain what causes the day/night cycle?
Q1: Is it day or night?
Q2: What causes the day/night cycle?
Q3: Can you explain this using a diagram?
Q4: Why do you think so?
Q5: Where did you first learn about this?

Question 4: explain why the phase of the Moon seems to change

Q1: What phases of the Moon have you seen?
Q2: Why do the phases of the Moon seem to change?
Q3: Can you explain this using a diagram?
Q4: Why do you think so?
Q5: Where did you first learn about this?

Question 5: explain what causes the change in seasons?

Q1: what season is it?
Q2: What causes the change in seasons?
Q3: Can you explain this using a diagram?
Q4: Why do you think so?
Q5: Where did you first learn about this?
APPENDIX D
INTERVIEW TRANSCRIPTS
INTERVIEW 1

Task 1.

R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you remember the question?
S: Yes.
R: Do you suppose that the size of the person relative to the Earth is reasonable?
S: No.
R: Do you have any idea about this? The Earth should be larger than this?
S: Yes.
R: And the person?
S: The person should smaller than this.
R: And the rock?
S: The rock should smaller than this.
R: Do you remember the question?
S: If the person drops the rock, in which direction will the rock fall?
R: In which direction?
S: Toward the center of the Earth.
R: (pointing to the different positions), in which direction will the rock fall?
S: All will fall toward the center of the Earth.
R: Why do you think so?
S: Because of gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday life?
S: Well, when we drop a pencil, it falls down.
R: Very good. Where did you first learn about this?
S: Science textbooks.

Task 2.
R: What is this?
S: The Earth.
R: What do you mean by N and S?
S: N means the North Pole and S means the South Pole.
R: There are two bottles of water at the North Pole?
S: Yes.
R: What are the states of the water in the two bottles?
S: Two bottles are filled with water. One bottle is open and the other bottle is closed.
R: Do you remember the question?
S: Yes. The question was that if we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram?
S: (drawing a diagram) Like this.
R: The water in the bottle flows out?
S: No. The water in bottles remains in the original state.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Where did you learn first about this?
S: From the science textbooks.

Task 3.
R: Is it day or night?
S: Day.
R: Later?
S: Night.
R: What causes day and night?
S: The Earth's rotation.
R: What do you mean by the Earth's rotation.
S: The Earth rotates once a day.
R: The Earth rotates once a day?
S: Yes.
R: Can you explain this using a diagram?
S: (drawing a diagram)
R: (pointing to the diagram) Where is the Sun?
S: Here.
R: Where is the Earth?
S: Here.
R: If the Earth faces the Sun?
S: It is day.
R: And the other side?
S: It is night.
R: Where did you learn first about this?
S: From science teachers and textbooks.

Task 4.
R: Do the phases of the Moon seem to change at night?
S: Yes.
R: What phases of the Moon do you see?
S: A full Moon, a half Moon.
R: Why do you think that the phases of the Moon seem to change at night? Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun, the Earth, and the Moon.
As far as I know, the Moon has the ability to reflect light. If the Moon reflects light too much, it is a full Moon...
R: (pointing to the diagram) What is the location of a full Moon with respect to the Earth?
S: Here.
R: And a half Moon?
S: Here
R: You mean that the phases of the Moon result from the different amount of light reflected by the Moon?
S: Yes
R: Where did you first learn this?
S: From teachers and science textbooks.
R: Do you mean teachers or science textbooks?
S: Teachers

Task 5.
R: We have four seasons; spring, summer, autumn, and winter.
R: What season is it?
S: Summer.
R: After summer?
S: Autumn.
R: What causes the change in seasons?
S: I think that it is the difference in the amounts of solar radiation. In summer, the Earth receives the largest amount of solar radiation. In winter, it receives the least amount of solar radiation.
R: What about autumn and spring?
S: The amounts of solar radiation are not less or greater. Just in between.
R: Can you explain this using a diagram?
S: (drawing a diagram) In summer, the Earth receives the largest amount of solar radiation. In winter, it receives the least amount of solar radiation.
R: You mean that the change in season results from the difference in the amount of solar radiation.
S: Yes.
R: Where did you learn first about this?
S: From science textbooks.
INTERVIEW 2

Task 1.
R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you suppose that the size of the person relative to the Earth is reasonable?
S: No.
R: Do you have any idea about this?
S: The Earth should be larger than this.
R: And the person?
S: The person is smaller than this.
R: And the rock?
S: The rock should be smaller than this.
R: Do you remember the question?
S: If the person drops the rock, in which direction will the rock fall?
R: Very good. In which direction?
S: Toward the center of the Earth.
R: (pointing to the diagram, the researcher asks the question of how the situation will change at three different places on the diagram) What do you think about the direction the rock will
fall?
S: All will fall toward the center of the Earth.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday life?
S: A magnet.
R: Anything else?
S: I am not sure.

Task 2.
R: What is this?
S: The Earth.
R: And this N and S?
S: The North Pole and the South Pole.
R: There are two bottles of water at the North Pole?
S: Yes.
R: One bottle is open and another is closed?
S: Yes.
R: Both bottles are filled with water
S: Yes.
R: Do you remember the question?
S: Yes. The question was that If we travel with the bottles to the
South Pole, what happens to the positions of the bottles and to
the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: Will the water in the bottle flows out?
S: No. The water in the bottles remains in the original state.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Great...

Task 3.
R: Is it day or night now?
S: Day.
R: When does night begin?
S: 8 p.m.
R: What causes day and night?
S: The Earth’s rotation. If the Earth faces the Sun, it is day. If not, it is night.
R: Can you explain this using a diagram?
S: The Earth rotates... (hesitating).
R: What causes day and night?
S: (hesitating)...If the Earth faces the Sun, it is day. If not, it is night.

Task 4.
R: Do the phases of the Moon seem to change at night?
S: Yes.
R: What phases of the Moon do you see?
S: Full Moon, a half Moon.
R: Why do you think that the phases of the Moon seem to change at night? Can you explain this using a diagram?
S: I think that it is the Earth's revolution.
R: (pointing to the diagram) If the Moon stays here, what kind of phases does the Moon look like?
S: A half Moon.
R: And here?
S: A full Moon.
R: Very good.

Task 5.
R: What season is it?
S: Summer.
R: After summer?
S: Autumn.
R: What causes the change in seasons? Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun. If the Earth is closed to the Sun, it is hot. That is summer. If the Earth is farther from the Sun, the Earth is cold. That is winter.
R: (pointing to the diagram) Can you explain this again?
S: Yes. Here is the Sun. If the Earth is closer to the Sun, it is hot. That is summer. If the Earth is farther from the Sun, the Earth is cold. That is winter.
R: Okay
INTERVIEW 3

Task 1.
R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you remember the question?
S: If the person drops the rock, in which direction would the rock fall?
R: Very good. In which direction?
S: Toward the center of the Earth.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday life?
S: Well, when we drop an apple, it falls down. Newton also said that.
R: If there was no gravity, what happens to us?
S: We would fly in the air.
R: Great

Task 2.
R: What is this?
S: The Earth.
R: What do you mean by N and S?
S: N means the North Pole and S means the South Pole.
R: There are two bottles of water at the North Pole.
S: Yes.
R: One bottle is open and another is closed?
S: Yes.
R: Do you remember the question?
S: Yes. The question was that if we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: The water in the bottle flow out?
S: No. The water in the bottles remains in the original state.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.

Task 3.
R: Is it day or night now?
S: Day.
R: Later?
S: Night.
R: What causes day and night?
S: The Earth’s revolution.
R: What do you mean by the Earth's revolution?
S: The Earth revolves around the Sun once a year.
R: How does the Earth's revolution cause the day/night cycle?
S: If the Sun faces the Earth, it is day. If not, it is night.
R: Is that because of the Earth's revolution?
S: It is because of the Earth's rotation.

Task 4.
R: Do the phases of the Moon seem to change at night?
S: Yes.
R: What phases of the Moon do you see?
S: No.
R: Did you observe them?
S: Yes.
R: What phases did you see?
S: A half Moon and a full Moon.
R: Why do you think that the phases of the Moon seem to change? Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun, the Earth, and the Moon. The Earth's shadow results in the phases of the Moon.
R: (pointing to the diagram) If the Moon stays here, what phases are the Moon?
S: A half Moon.
R: And here?
S: A full Moon.
R: Very good.
Task 5.
R: What season is it?
S: Summer.
R: After summer.
S: Autumn.
R: What causes the change in seasons?
S: The Earth's rotation.
R: The Earth's rotation? Can you explain this using a diagram.
S: (drawing a diagram) Here is the Sun. (hesitating).
R: How does the Earth's rotation cause the change in seasons?
S: I am not sure.
INTERVIEW 4

Task 1
R: What is this (pointing at the picture)?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you remember the question?
S: If the person drops the rock, in which direction would the rock fall?
R: Very good. In which direction?
S: The rock would fall downward (students dropped an eraser as an example).
R: Where is the North pole?
S: Here.
R: Where is the Equator?
S: (hesitating).
R: Here. Okay?
S: Yes.
R: If the person drops the rock here, in which direction would the rock fall?
S: (hesitating).
R: Where did you first learn about this?
S: That's just what I thought.
R: Can you give me an example of gravity in everyday life?
S: When I drop an eraser, it falls down.
R: Okay.

Task 2.
R: What is this?
S: The Earth.
R: And this N and S?
S: The North Pole and the South Pole.
R: There are two bottles of water at the North Pole?
S: Yes. One bottle is open and another is closed.
R: Both bottles are filled with water
S: Yes.
R: Do you remember the question?
S: Yes. The question was that if we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: What happens to the position of the bottles?
S: Like this.
R: The water in the bottle flow out?
S: No. The water in the bottles remains in the original state.
R: Why do you think so?
S: Gravity. The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday experience?
S: If the Earth did not have gravity, we could not live.
Task 3.
R: Is it day or night now?
S: Day.
R: What causes day and night?
S: The Earth's rotation. If the Earth faces the Sun, it is day. If not, it is night.
R: Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun. (hesitating)...If the Earth faces the Sun, it is day. If not, it is night.
R: Why don't we feel about the Earth's rotation?
S: All things on the Earth rotate at the same speed.
R: All things on the Earth rotates at the same speed?
S: Yes.

Task 4.
R: Do the phases of the Moon seem to change at night?
S: Yes.
R: Can you show me what phases of the Moon you see?
S: (hesitating).
R: I mean, What phases of the Moon do you see?
S: From a full Moon to a half Moon.
R: Why do you think that the phases of the Moon seem to change?
S: (hesitating).
R: Can you explain this using a diagram?
S: (drawing a diagram).
R: (pointing to the diagram) Where is the Sun?
S: Here.
R: (pointing to the diagram) If the Moon stays here, what kind of phase does the Moon have?
S: I am not sure. A full Moon.
R: Where is the observer?
S: Here
R: Why do you think that the phases of the Moon seem to change at night?
S: The Earth rotates and revolves around the Sun.
R: The Earth rotates and revolves around the Sun?
S: Yes
R: Are you sure?
S: I am not sure.

Task 5.
R: What season is it?
S: Summer.
R: After summer?
S: Autumn.
R: What causes the change in seasons?
S: If the Earth is closer to the Sun, it is hot. That is summer. If the Earth is farther from the Sun, the Earth is cold. That is winter.
R: (pointing to the diagram) Can you explain this again?
S: Yes. Here is the Earth and the Sun. If the Earth is closer to the Sun, it is hot. That is summer. If the Earth is farther from the
Sun, the Earth is cold. That is winter.

R: What about spring and autumn?

S: The distance is not less or greater. Just in-between.
Task 1.

R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Is the Earth too small?
S: Yes
R: Actually the Earth should be larger and the person should be smaller...
S: Yes.
R: Do you remember the question?
S: If the person drops the rock, in which direction would the rock fall?
R: Very good. In which direction? Can you explain this using a diagram?
S: (drawing a diagram) Like this. Toward the center of the Earth.
R: (pointing to the diagram, the researcher asks the question of how the situation will change at three different places on the diagram) What do you think about the direction of the rock will fall?
S: All will fall toward the center of the Earth.
R: Why do you think so?
S: I am not sure, but....Toward the center of the Earth.

Task 2.
R: What is this?
S: The Earth.
R: And N and S?
S: The North Pole and the South Pole.
R: And this?
S: Two bottles of water.
R: There are two bottles of water at the North Pole?
S: Yes.
R: One bottle is open and another is closed?
S: Yes.
R: Do you remember the question?
S: Yes. The question was that If we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: The water in the bottle flows out?
S: No. The water in the bottles remains in the original state.
R: Why do you think so?
S: Air pressure.
R: Air pressure?
S: Yes.
R: ..........
Task 3.
R: Is it day or night now?
S: Day.
R: Later?
S: Night.
R: What causes day and night?
S: The Earth's revolution.
R: What do you mean by the Earth's revolution. Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun, the Moon, and the Earth. The Earth revolves around the Sun. (hesitating) The shadow of the Earth....
R: Can you explain this using a diagram again?
S: I am not sure....

Task 4.
R: Do the phases of the Moon seem to change at night?
S: Yes.
R: What phases of the Moon do you see?
S: (hesitating) Full Moon, a half Moon......
R: Why do you think that the phases of the Moon seem to change at night? Can you explain this using a diagram?
S: (drawing a diagram) The Moon has phases because of the Earth's shadow.
R: (pointing to the diagram) What is the location of a full Moon and a half Moon with respect to the Earth?
S: (hesitating) If the shadow of the Earth is small, the Moon is a half Moon.
R: Can you explain this again?
S: I am not sure.
R: Why do the phases of the Moon seem to change at night?
S: (hesitating) I am not sure.

Task 5.
R: What season is it?
S: Summer.
R: After summer?
S: Autumn.
R: After autumn?
S: Winter...Spring.
R: What causes the change in seasons?
S: Difference in solar radiation.
R: Difference in solar radiation? Can you explain this using a diagram?
S: (drawing a diagram) The Sun illuminates the Earth differently. That is the cause of change in seasons.
R: What is the position of the Earth with respect to the Sun during a summer, winter, spring, autumn?
S: (pointing to the diagram) This side.....
INTERVIEW

Task 1
R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: The Earth is too small?
S: No.
R: How about this person?
S: I think that this person should be smaller and the Earth should be larger.
R: This picture is reasonable?
S: Yes.
R: Yes? The Earth is too small like this? Actually this picture is not reasonable? Right?
S: Yes.
R: If the person drops the rock, in which direction will the rock fall?
S: Toward the center of the Earth.
R: (pointing to the diagram, the researcher asks the question of how the situation will change at three different places on the diagram) What do you think about the direction the rock will fall?
S: Toward the center of the Earth.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday life?
S: We stand on the Earth without falling off.
R: Another example?
S: An apple falls down to the ground.
R: Where did you first learn about this?
S: In science class.
R: When?
S: Grade 7th.
R: Who's your science teacher?
S: Seo (last name).
R: You like her?
S: Yes.

Task 2.
R: This is the Earth?
S: Yes.
R: And this?
S: The South Pole.
R: And this?
S: The North Pole?
R: And this?
S: Two bottles of water.
R: What is the question?
S: (students recalls this question) If we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: Positions of the bottles?
S: There are the same.
R: What about the water in the bottles?
S: It is frozen.
R: Frozen?
S: Yes.
R: If does bottles were taken to the Equator, what would happen to the water in the bottles?
S: I think that the water in the opened bottle will evaporate.
R: Evaporate? Why?
S: The Equator is hot.

Task 3.
R: There is day and night?
S: Yes.
R: What causes day and night?
S: The Earth's rotation.
R: Can you give me example using a diagram?
S: (drawing diagram).
R: Where is Korea?
S: (pointing to diagram) Here. If the Earth faces the Sun, it is day.
R: Do you feel that the Earth rotates?
S: No.
R: Why?
S: The Earth rotates too fast.
R: The Earth rotates too fast? If the Earth rotates slow, you feel that the Earth rotates?
S: (hesitating).
R: You understand this?
S: I am not sure.

Task 4.
R: We see the different phases of the Moon on a clear night?
S: yes.
R: What causes them?
S: Something blocks the Moon.
R: Something?
S: (hesitating).
R: Where is the observer?
S: (hesitating).
R: Why do the phases of the Moon seem to change at night?
   Something blocks the Moon? Like what?
S: (hesitating).
R: Can you explain this using this diagram?
S: Here is the Moon, the Sun, and the Earth. (hesitating).
R: Can you explain this in more detail?
S: The Earth revolves?
R: What is the location of a full Moon with respect to the Earth? A half Moon?
S: Here... Here

Task 5.
R: We have summer, autumn, winter, and spring?
S: Yes.
R: What season is it?
S: Summer.
R: Summer? After summer?
S: Autumn, winter, spring.
R: What causes the change in seasons?
S: The Earth revolves around the Sun.
R: The Earth's revolution?
S: Yes.
R: What do you mean by the Earth's revolution?
S: The Earth revolves around the Sun once a year.
R: Can you explain this using a diagram?
S: (pointing to the diagram) The Earth revolves.. (hesitating).
INTERVIEW 7

Task 1.
R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you remember the question?
S: If the person drops the rock, in which direction would the rock fall?
R: Very good. In which direction?
S: Toward the center of the Earth.
R: (pointing to the diagram, the researcher asks the question of how the situation will change at four different places on the diagram).
What do you think about the direction the rock will fall?
S: Toward the center of the Earth.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday life?
S: Where we drop a heavy thing and light thing, the former will fall down first.
R: Where did you first learn about this?
S: In school and in the textbook.
R: What do you mean by gravity?
S: Gravity means that we drop something, it falls down.

Task 2.
R: This is the Earth?
S: Yes.
R: This is the South Pole, the North Pole?
S: Yes.
R: There are two bottles of water? If we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: Do the two bottles of water remain in the original state?
S: Yes.
R: Why do you think so?
S: Gravity.
R: How about the water? Does the water flow out?
S: No.
R: Why do you think so?
S: Gravity.

Task 3.
R: There is day and night?
S: Yes.
R: What causes day and night?
S: The Earth's rotation.
R: What do you mean by the Earth's rotation?
S: The Earth rotates once a day.
R: If the Earth did not rotate, what would happen?
S: On one side of the Earth it is always day and on the other side it is night.
R: Why don't we feel the Earth's rotation?
S: I am not sure...

Task 4.
R: At night, do the phases of the Moon seem to change?
S: Yes.
R: What phases of the Moon do you see?
S: Full Moon, a half Moon.
R: Why do the phases of the Moon seem to change at night?
S: Because of the shadow of the Earth.
R: Can you draw a diagram?
S: (drawing a diagram) Here is the Earth, the Sun, and the Moon.
R: Where is the observer?
S: (pointing to the diagram) Here is the observer.
R: Does Earth's shadow cause the different phases of the Moon?
S: Yes.

Task 5.
R: We have summer, autumn, winter, and spring?
S: Yes.
R: What season is it?
S: Summer.
R: Summer? After summer?
S: Autumn, winter, spring.
R: What causes the change in seasons?
S: The Earth revolves around the Sun.
R: The Earth's revolution?
S: Yes.
R: Can you explain this using a diagram?
S: (pointing to the diagram) When the Earth is closer to the Sun, it is summer.
R: Any other reasons?
S: No.
Task 1.
R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: If the person drops the rock, in which direction would the rock fall?
S: Toward the center of the Earth.
R: (pointing to the diagram, the researcher asks the question of how the situation will change at three different places on the diagram) What do you think about the direction the rock will fall?
S: Toward the center of the Earth.
R: (pointing to the diagram) What is the position of the person at the North Pole?
S: Like this.
R: At the South Pole?
S: Like this.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday life?
S: In case we stand on the Earth. (hesitating) the Moon....

Task 2.
R: Is this the Earth?
S: Yes.
R: And this?
S: The South Pole.
R: And this?
S: The North Pole?
R: And this?
S: Two bottles of water.
R: One bottle is open? The other bottle is closed?
S: Yes.
R: What is the question?
S: If we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: Positions of the bottles?
S: The same.
R: What about the water in the bottles?
S: Frozen.
R: Frozen?
S: Yes.
R: If the bottles are taken to the Equator, What happens to the water
in the bottles?
S: I think that the water remains in the original state.
R: Why?
S: Gravity.
R: What happens to the water at the South Pole?
S: Frozen.

Task 3.
R: There is day and night?
S: Yes.
R: What causes day and night?
S: The Earth's rotation. If the Earth faces the Sun, it is day. If not, it is night. (hesitating).
R: I will ask you the question again. What causes day and night?
Can you give me example using a diagram?
S: (drawing diagram) The Earth rotates.
R: What do you mean by the Earth's rotation?
S: The Earth rotates.
R: If the Earth does not rotate, what happens to us?
S: We wouldn't have any day/night cycle.
R: Okay.

Task 4.
R: Are there the different phases of the Moon at night?
S: yes.
R: What causes them? Can you explain this using a diagram?
S: (drawing a diagram) Here is the Moon, the Sun, and the Earth. The Moon receives sunlights and reflects it.

R: Where is the Moon?
S: Here.

R: Where is the Earth?
S: (hesitating) The Moon...

R: Why do the phases of the Moon seem to change at night?
S: (hesitating) The Moon receives sunlights and reflects it. The phases of the Moon result from the different amounts of light reflected by the Moon.

R: Can you explain this using a diagram?
S: Here is the Moon, the Sun, and the Earth. (hesitating).

R: You understand this?
S: I am not sure.

Task 5.

R: What causes the change in seasons?
S: The Earth revolves around the Sun.

R: Can you explain this using a diagram.
S: (drawing a diagram) Here is the Sun, ....Because of the Earth's revolution, we have seasons.

R: (pointing to the diagram) What is the position of the Earth with respect to the Sun during summer?
S: Here.

R: Spring?
S: Here.
R: Autumn?
S: Here.
R: Why do you think so?
S: The Earth revolves around the Sun once a year. (hesitating).
R: Can you explain this using a diagram?
S: (pointing to the diagram) The Earth revolves.. (hesitating).
R: You understand this?
S: I am not sure.
Task 1.
R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Is the Earth small like this?
S: No.
R: Do you suppose the size of the person relative to the Earth is reasonable?
S: I don't think so.
R: You are right. Where does the person stand?
S: On the Earth.
R: You are right. If somebody drops the rock, in which direction would the rock fall? Can you explain this using a diagram?
S: Toward the center of the Earth.
R: (pointing to the diagram, the researcher asks the question of how the situation will change at four different places on the diagram) What do you think about the direction the rock will fall?
S: Toward the center of the Earth.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday experience?
S: An apple falling down.
R: In which direction will it fall?
S: Downward?
R: Anything else?
S: I am not sure.
R: That's okay.

Task 2.
R: Do you remember this picture?
S: Yes.
R: What is the question?
S: If we travel with two bottles of water to the South Pole, what happens to the positions and to the water in the bottles?
R: You are right. Can you tell me about that?
S: The water in the bottles remains in the original state.
R: Why do you think so?
S: The force of the Earth that attracts something.

Task 3.
R: Is it day?
S: Yes.
R: Why do we have day and night?
S: Because of the Earth's rotation.
R: What do you mean by the Earth's rotation?
S: The Earth rotates once a day.
R: Do you feel the Earth's rotation?
S: No.
R: Can you explain the Earth's rotation using a diagram?
S: (drawing a diagram) This side is day and the other side is night.

Task 4.
R: We see the different phases of the Moon at night?
S: Yes.
R: Did you observe them?
S: Yes.
R: Why do the phases of the Moon seem to change at night?
S: (drawing a diagram and explaining) The Earth revolves around the Sun.
R: Where does the observer stand in your diagram?
S: In the center of the Earth.
R: In the center of the Earth?
S: I am not sure.
R: Are you confused about this question?
S: Yes.

Task 5.
R: We have spring, summer, autumn, and winter?
S: Yes.
R: What season is it?
S: Summer.
R: After summer, what is the next season?
S: Autumn.
R: What causes the change in seasons?
S: The Earth revolves around the Sun.
R: Can you explain this using a diagram?
S: (drawing a diagram) the Sun and the Earth.
R: (pointing to the diagram) Which side is summer?
S: (hesitating).
R: Are we living in the northern hemisphere or the southern hemisphere?
S: Northern hemisphere.
INTERVIEW 10

Task 1

R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you suppose the size of the person relative to the Earth is reasonable?
S: I don't think so.
R: The Earth should be larger than this and the person should be smaller than this person?
S: Yes.
R: If somebody drops the rock, in which direction would the rock fall?
S: Toward the center of the Earth.
R: (pointing to the diagram, the researcher asks the question of how the situation will change at four different places on the diagram) What do you think about the direction the rock will fall?
S: Toward the center of the Earth.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday experience?
S: When we drop a ball, the ball falls down.
R: In which direction would it fall?
S: Downward?
R: That's okay.

Task 2.
R: What is this?
S: The Earth.
R: And this?
S: Two bottles of water.
R: One bottle is open and the other bottle is closed?
S: Yes.
R: What is the question?
S: If we travel with two bottles of water to the South Pole, what happens to the positions of the bottles and to the water in the bottles?
R: You are right. Can you explain using a diagram?
S: (drawing a diagram) The water in the bottles remains in the original state.
R: Why do you think so?
S: The force of the Earth that attracts something.
R: Gravity?
S: Yes.

Task 3.
R: Why do we have day and night?
S: Because of the Earth's rotation.
R: Can you explain this using a diagram?
S: (using a diagram) Here is the Sun and the Earth, if the Sun faces the Earth, it is day, and the other side is night.
R: Why do you think so?
S: The Earth's rotation.
R: What do you mean by the Earth's rotation?
S: The Earth rotates once a day.
R: Very good.

Task 4.
R: We see the different phases of the Moon at night?
S: Yes.
R: Did you observe them?
S: Yes.
R: Why do the phases of the Moon seem to change at night?
S: (drawing a diagram and explaining) Here is the Sun, the Earth, and the Moon.
R: Where does the observer stand in your diagram?
S: (pointing to the diagram) Here.
R: Well, why do the phases of the Moon seem to change at night?
S: (hesitating) I am not sure.
R: (keep asking this question)........
S: (hesitating).
Task 5.

R: What causes the change in seasons?
S: The Earth revolves around the Sun once a year.
R: Can you explain this using a diagram?
S: (drawing a diagram)
R: Where is the Sun?
S: Here.
R: And the Earth?
S: Here. (pointing to diagram) If the Earth is here, the Earth receives more light. If the Earth moves somewhere else, the Earth receives less light.
R: (pointing to the diagram) Where is the northern hemisphere or southern hemisphere?
S: (hesitating) The Earth's axis tilts.
R: Which side is summer in the northern hemisphere and which side is summer in the southern hemisphere?
S: (hesitating) Here.
R: Are you confused about this?
S: Yes.
R: What causes the change in seasons?
S: Because of the Earth's revolution.
R: Can you explain this in more detail?
S: (hesitating).
INTERVIEW 11

Task 1
R: What is this?
S: The Earth.
R: What is this?
S: A person
R: The person has a rock?
S: Yes.
R: Do you think the size of the person relative to the Earth is reasonable?
S: I don't think so.
R: What's the real size of the person relative to the Earth?
S: The person should be smaller than this.
R: What next?
S: The Earth should be larger than this.
R: What next?
S: The Earth is not a real circle.
R: Why do you think so?
S: I am not sure. But, I learned it in middle school.
R: Okay. When the person drops the rock, in which direction will the rock fall? Can you draw a diagram?
S: (drawing a diagram) Like this. Toward the center of the Earth.
R: Why do you think so?
S: I am not sure. But, maybe gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday experience?
S: The Earth and the Sun.
R: The Earth and the Sun?
S: Yes.
R: Can you give me an example of gravity in everyday experience?
S: When I was young, I grew up in the countryside. I saw apples falling down. This is an example of gravity in everyday life.
R: How did the apples fall down?
S: They fell to the ground.
R: How?
S: I am not sure.

Task 2.
R: You saw this diagram?
S: Yes.
R: What is this?
S: The Earth.
R: What is this?
S: The bottles of water.
R: What's this?
S: This bottle is open and that is closed.
R: If somebody takes these bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain using a diagram?
S: (drawing a diagram) Like this.
R: The water flows out?
S: I don't think so.
R: Why do you think so?
S: Gravity.
R: Okay. Very good.

Task 3.
R: There is day and night?
S: Yes.
R: What causes day and night?
S: I think that the Earth rotates.
R: What do you mean by the Earth's rotation?
S: The Earth rotates once a day.
R: Can you explain this using a diagram?
S: (drawing a diagram) Like this.
R: Do you feel that the Earth rotates?
S: I don't think so.
R: Do you feel that the Sun moves?
S: Yes.
R: Why do you tell me that the Earth moves?
S: Theory of relativity.
R: Theory of relativity?
S: (hesitating).

Task 4.
R: We see the Moon at night?
S: Yes. Sometimes, we can't see it.
R: Yes. In a cloudy night, we can't see it, right?
S: Yes.
R: Why do the phases of the Moon seem to change?
S: I think that different amounts of light were reflected by the Moon at different times.
R: Can you explain using a diagram?
S: (drawing a diagram) Here is the Sun, the Moon, and the Earth.
R: Where does the observer stand?
S: (pointing to the diagram) Here.
R: Why do the phases of the Moon seem to change?
S: (hesitating) The Moon reflects sunlight.
R: (pointing to the diagram) If the observer stands here, what is the phases of the Moon?
S: I am not sure.

Task 5.
R: We have summer, autumn, winter, and spring?
S: Yes.
R: What causes the change in seasons?
S: The Earth's axis tilts when the Earth revolves.
R: Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun and the Earth. The Earth's axis is tilted. And then, if the Earth's axis is tilted like this, the solar altitude is higher, and so the Earth receives more sunlight. That is summer.
R: What do you mean by solar altitude?
S: Incident angle.
R: Incident angle?
S: Yes. If the incident angle is larger, the Earth's temperature is higher.
R: What do you mean by the Earth's revolution?
S: I think the Earth revolves around the Sun once a year.
R: That is okay.
Task 1.

R: What is this?
S: The Earth.
R: And this?
S: A person.
R: And this?
S: A rock.
R: Do you remember the question?
S: Yes.
R: Do you suppose that the size of the person relative to the Earth is reasonable?
S: No.
R: Do you have any idea about this? The Earth should be larger than this?
S: Yes.
R: And the person?
S: The person is smaller than this.
R: Do you remember the question?
S: If the person drops the rock, in which direction would the rock fall?
R: Very great. In which direction?
S: Toward the center of the Earth.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Can you give me an example of gravity in everyday life?
S: Well, when we drop an apple, it falls down. Newton also said that.
R: Very great. Where did you first learn about this?
S: Teachers explained this in the science classes and I read about it in the textbook.

Task 2.
R: What is this?
S: The Earth.
R: What do you mean by N and S?
S: N means the North Pole and S means the South Pole.
R: There are two bottles of water at the North Pole?
S: Yes.
R: One bottle is open and another is closed?
S: Yes.
R: Do you remember the question?
S: Yes. The question was that if we travel with the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles? Can you explain this using a diagram.
S: (drawing a diagram) Like this.
R: The water in the bottle flow out?
S: No. The water in the bottles will remain in the original state.
R: Why do you think so?
S: Gravity.
R: What do you mean by gravity?
S: The force of the Earth that attracts something.
R: Where did you learn first about this?
S: In science classes.

Task 3.
R: Is it day or night now?
S: Day.
R: Later?
S: Night.
R: Is it bright during day?
S: Bright.
R: What causes day and night?
S: The Earth's rotation.
R: What do you mean by the Earth's rotation?
S: The Earth rotates once a day.
R: The Earth rotates once a day?
S: Yes.
R: Can you explain this using a diagram?
S: (drawing a diagram) Here is the Earth. If the Earth faces the Sun, it is day. And the other side is night.
R: Where did you first learn about this?
S: From science teachers.

Task 4.
R: Do the phases of the Moon seem to change at night?
S: Yes.
R: What phases of the Moon do you see?
S: Full Moon, a half Moon.
R: Why do you think that the phases of the Moon seem to change?
   Can you explain this using a diagram?
S: (drawing a diagram) Here is the Sun, the Earth, and the Moon. The changing positions of the Earth, the Sun, and the Moon allow us to see different amounts of the lighted part of the Moon at different times.
R: (pointing to the diagram) If the Moon stays here, what does the Moon look like?
S: A half Moon.
R: And here?
S: A full Moon.
R: Very good

Task 5:
R: What kinds of seasons do we have?
S: Spring, summer, autumn, and winter.
R: What season is it?
S: Summer.
R: Summer. Is summer hot?
S: Yes.
R: How about winter?
S: It is very cold.
R: What causes the change in seasons?
S: The Earth revolves once a year around the Sun. The Earth revolves in a circular orbit. If the Earth is closer to the Sun, it is hot. That is summer. If the Earth is farther from the Sun, the Earth is cold. That is winter.

R: You mean that when the Earth is closer to the Sun, the Earth receives more heat, and when the Earth is farther from the Sun, the Earth receives less heat?

S: Yes. I am not sure.

R: Where did you learn first about this?

S: From reference books and textbooks.
INTERVIEW

Task 1

R: You saw this picture, right?
S: Yes.
R: Can you draw another diagram here?
S: Yes. (drawing a diagram)
R: What is this?
S: The Earth.
R: What is this?
S: A person.
R: What is this?
S: A rock.
R: Do you suppose the size of the person relative to Earth and the rock is reasonable?
S: No.
R: What is your idea about this?
S: The Earth is larger than this......
R: When the person is going to drop the rock, in which direction would the rock fall?
S: Toward the center of the Earth.
R: And then?
S: Because the Earth rotates from the west to the east, the rock falls like this (pointing to the diagram).
R: You say that the Earth rotates from the west to the east, the rock falls like that?
S: Yes.
R: The rock does not fall toward the center of the Earth?
S: It may fall at an angle toward the surface of the Earth because of the Earth's rotation.
R: Does the fall of the rock result from gravity?
S: Yes.
R: What do you mean by gravity?
S: The force that the planets including the Earth attract objects.
R: Can you give me a good example of gravity in everyday life?
S: I think that gravity is related to the fact that a person stands on the Earth.
R: What happens to a person if there is no gravity on the Earth?
S: He will fall up.

Task 2.
R: What's this?
S: The Earth.
R: What do N and S mean?
S: South Pole and North Pole.
R: And this?
S: Two bottles of water.
R: One bottle is open and another is closed?
S: Yes.
R: Do you remember the question?
S: Yes.
R: Please tell me?
S: As I remember, the question was that if the person takes two bottles of water to the South Pole, What happens to the positions of the bottles and to the water in the bottles?
R: You have a good memory. Can you draw a diagram?
S: (drawing a diagram) Like this. I think that the water in the bottles remains in original state.
R: Why?
S: The water might be frozen because the temperature is below zero both in the South Pole and at the North Pole?
R: If someone takes those bottles from the west to the east along the Equator, what happens to those bottles of water?
S: The same.
R: The same with both Poles and both Equators?
S: No. The water in the bottles on the east part of the Equator will be less because the temperature is above zero.
R: Because this area is hot?
S: Yes.

Task 3.
R: There is day and night, right?
S: Yes.
R: What causes day and night?
S: The Earth's axis is tilted.
R: Can you explain this using a diagram?
S: (drawing a diagram) The Earth rotates.
R: Where is the Sun and the Earth?
S: (pointing to the diagram) Here is the Sun and the Earth.
R: Where is day and night?
S: (pointing to the diagram) This side is day and the other side is night.
R: Why do you think so?
S: The Earth's axis is tilted and the Earth rotates.
R: What do you mean by the Earth's rotation?
S: The Earth rotates by itself.

Task 4.
R: We have the different phases of the Moon everyday?
S: Yes.
R: Why do the phases of the Moon seem to change?
S: The Earth rotates and revolves around the Sun. And the Moon revolves around the Sun. And so, the different phases of the Moon result from different amount of light reflected by the Moon.
R: Can you explain this using a diagram?
S: (drawing a diagram) Like this.
R: Where is an observer?
S: (pointing to the diagram) Here.
R: Here is the Sun, the Moon, and the Earth?
S: Yes.
R: If the observer stands here, what kind of phases does the Moon here?
S: I think a full Moon.
R: Why do you think so?
S: The Moon reflects as much sunlight as it receives.
R: The Moon's reflection?
S: Yes. (hesitating).
Task 1
R: What does the circle represent?
S: Earth.
R: Earth. Is this the person?
S: Yes.
R: Do you suppose the size of the person relative to the Earth is reasonable?
S: I don't think so.
R: You're right. What do you think about the actual size of the person relative to the Earth?
S: I think that the Earth is larger than this and the person is smaller than this person.
R: Very good. You suppose that this person stands on the Earth, has a rock in his hand, and is going to drop the rock. In which direction would the rock fall?
S: (pointing to the picture) This way because the Earth has gravity.
R: Can you draw the diagram?
S: (drawing a diagram) Like this.
R: In which direction would gravity pull on an object?
S: Like this.
R: What do you mean by gravity?
S: The force of the Earth that attracts the Moon.
R: Can you tell me a good example which shows gravity in everyday experience?
S: When we toss a ball into the air, it drops toward the center of the Earth.
R: How does the ball fall?
S: In a circular path.
R: Do you have another example of gravity in everyday experience?
S: When a suspended object falls down, that's an example of gravity.
R: In this case, the object falls in a circular path?
S: I am not sure.
R: Are you confused about this?
S: Yes.
R: Okay.

Task 2.
R: (pointing to the picture) What are these?
S: Two bottles.
R: What are these bottles filled with?
S: Water.
R: Do you suppose that two bottles stand on the North Pole?
S: Yes.
R: If a person takes the bottles to the South Pole, what happens to the positions of the bottles and to the water in the bottles?
S: The water in the bottles remains in the original state.
R: Can you draw a diagram?
S: (drawing a diagram) Like this.
R: Your diagram indicates that the water in the bottles remains in the original state?
S: Yes.
R: Why do you think so?
S: Gravity.
R: Gravity? What do you mean by gravity?
S: The force which attracts objects.
R: Gravity makes the two bottles of water remain in the original state?
S: Yes.
R: That is gravity?
S: Yes.

Task 3.
R: There is day and night?
S: Yes.
R: What causes day and night?
S: The Earth's rotation.
R: The Earth's rotation? What do you mean by the Earth's rotation?
S: I think that the Earth rotates around the Sun once a day.
R: Do you feel that the Earth rotates?
S: No.
R: Why do you think so?
S: The speed of the Earth's rotation is too fast.
R: The speed of the Earth's rotation is too fast? And so, you don't feel it.
S: Yes.
R: Isn't it very interesting?
Task 4.

R: After the Sun sets, you see the phases of the Moon.
S: Yes.
R: You see a full Moon, a waxing Moon, and a waning Moon.

Why do the phases of the Moon seem to change? Can you draw a diagram?
S: (drawing a diagram) Here is the Sun, the Earth, and the Moon.
R: Where does the person stand in this diagram?
S: The person? (pointing to the diagram) Here.
R: Here? What is the person looking at?
S: I am not sure.
R: (pointing to the diagram) You draw the diagram like this. Is the distance between the Sun, the Earth, and the Moon too short?
S: I am not sure.
R: Anyway, you see the different phases of the Moon everyday?
S: Yes.
R: You have my point. What causes the different phases of the Moon everyday?
S: The position of the Moon.
R: The position of the Moon with respect to the Earth? Can you explain more?
S: (hesitating to answer the question) I am not sure.
R: We have summer, autumn, winter, and spring.
S: Yes.
R: What causes the change in seasons?
S: I think that the Earth revolves around the Sun.
R: The Earth's revolution?
S: The Earth revolves around the Sun once a year.
R: Can you draw a diagram?
S: (drawing a diagram) Like this.
R: (pointing to the diagram) Which sides is summer, autumn, winter, and spring? Which hemisphere are we living in?
S: The northern hemisphere. (pointing to the diagram) Here is summer.
R: Where is summer in the northern hemisphere in this case?:
S: (hesitating).
R: You are confused?
S: Yes.
INTERVIEW 15

Task 1
R: What are these?
S: Earth, rock, and people.
R: Do you suppose the size of the person relative to the Earth is reasonable?
S: Yes.
R: Is the actually the Earth larger than this? And, Is person smaller than this?
S: Yes.
R: Do you understand this?
S: Yes.
R: If the rock falls, in which direction would the rock fall?
S: Toward the center of the Earth.
R: Why would it fall that way?
S: Gravity.
R: What do you mean by gravity?
S: I don't know.
R: But, you don't actually know the meaning of gravity?
S: Yes, but I have heard about it.

Task 2.
R: What are these?
S: The Earth and two bottles of water.
R: One bottle is closed and another is open?
S: Yes.
R: What do N and S mean?
S: North Pole and South Pole?
R: If somebody takes these bottles to the South Pole, What happens to these bottles and to the water? I can draw the Earth here for you.
S: (The student draw the two bottles of water on the South Pole) Like this.
R: Does the water in the bottles flow out?
S: No.
R: Why do you think so?
S: (The student remained silent)
R: Why do you think so?
S: I don't know.

Task 3:
R: There is day and night.
S: Yes.
R: Why is it dark at night and light and during the day?
S: The Earth rotates.
R: Why do you think so?
S: The Earth rotates.
R: Do you think that the Earth rotates?
S: No.
R: Why did you say that the Earth rotates?
S: I learned it in science class.
R: Do you explain why the Earth rotates by using the globe?
S: Sure. (He is demonstrating his think on this topic)
R: This side is day?
S: Yes.
R: This side is night?
S: Yes.
R: Very good! Ok. What do you call this phenomena?
S: The Earth's rotation

Task 4
R: Can we see the Moon at night?
S: Yes. Can we see it during the day?
R: No. Why do You think so?
S: Sunlight.
R: Can we see it on a cloudy day?
S: No.
R: Why do the phases of the Moon seem to change?
S: Because the Moon moves.
R: Can you explain to me by drawing pictures?
S: Sure. Here is a waxing Moon and a waning Moon.
R: Why do the phases of the Moon seem to change?
S: (The student remained silent about thirty seconds) The Earth's revolution.

Task 5.
R: What causes the change in seasons?
S: The Earth revolves around the Sun.
R: Why do you think so?
S: The Earth revolves around the Sun.
R: The Earth revolves around the Sun?
S: Yes.
R: Can you show me that?
S: (The student did not respond).
APPENDIX E

SOURCES OF NAIVE THEORIES
### Sources of Naive Theories as Identified by Students

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Grade</th>
<th>Naive theories</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>The rock would fall downward (see response group 2 in Table 9)</td>
<td>A</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>The rock would fall at an angle toward the surface of the Earth (see response group 3 in Table 9)</td>
<td>B</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>The bottom of the bottles would be toward the center of the Earth and the water in the bottles would be frozen</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>The bottom of the bottles would be toward the center of the Earth and the water in the bottles would be frozen</td>
<td>B</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>The change in the day/night cycle is due to the Earth’s revolution</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>The phases of the Moon are due to the different amounts of light reflected by the Moon</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>The phases of the Moon are due to the different sizes of the Earth’s shadow</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>The phases of the Moon are due to the Earth’s rotation and revolution</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>The phases of the Moon are due to the different sizes of the Earth’s shadow</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>The phases of the Moon are due to the different sizes of the Earth’s shadow</td>
<td>D</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>The phases of the Moon are due to the different amounts of light reflected by the Moon</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>The phases of the Moon are due to the Earth’s revolution</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>The phases of the Moon are due to the</td>
<td>C</td>
</tr>
<tr>
<td>Page</td>
<td>Question</td>
<td>Option</td>
<td></td>
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<td>------</td>
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<td></td>
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<tr>
<td>4</td>
<td>The phases of the Moon are due to the different amounts of light reflected by the Moon</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>The phases of the Moon are due to the different sizes of the Earth's shadow</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the different amounts of solar radiation</td>
<td>C &amp; E</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the relative distance between the Sun and the Earth</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the Earth's rotation</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the relative distance between the Sun and the Earth</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the different amounts of solar radiation</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the Earth's revolution</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the relative distance between the Sun and the Earth</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the Earth's revolution</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the Earth's revolution</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the relative distance between the Sun and the Earth</td>
<td>B &amp; C</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the Earth's revolution</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The change in seasons is due to the Earth's revolution</td>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>
A: personal experiences  B: teachers  C: textbooks
D: other books  E: instructional television
APPENDIX F

COMPARISON OF INTTETE AND INTERVIEW
A Comparison of the Open-Ended Written Questions (INTTES) and the Interview of Identifying Naive Theories

<table>
<thead>
<tr>
<th>Student Grade</th>
<th>Item INTTES</th>
<th>Interview</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>1 Toward center of Earth; gravity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Toward center of Earth; remain in</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>original state; gravity</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>3 Earth's rotation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Different amounts of light reflected</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>by the Moon</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>5 Relative difference in solar radiation</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>1 Toward center of Earth; gravity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Toward center of Earth; remain in</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>original state; gravity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Moon blocks light during the night</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Moon's revolution</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Relative distance between Sun and Earth</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>1 Toward center of Earth; gravity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Toward center of Earth; remain in</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>original state; gravity</td>
<td></td>
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</table>

* Indicates a unique response.
<table>
<thead>
<tr>
<th></th>
<th>Earth's revolution</th>
<th>Earth's rotation</th>
<th>Earth's rotation</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>Differences in the sizes of Earth's shadow</td>
<td>Differences in the sizes of Earth's shadow</td>
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<tr>
<td>5</td>
<td>Earth's rotation</td>
<td>Earth's rotation</td>
<td>*</td>
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<td>4</td>
<td>6</td>
<td>1</td>
<td>Toward center of Earth; gravity</td>
</tr>
<tr>
<td>2</td>
<td>Toward center of Earth; remain in original state; gravity</td>
<td>Toward center of Earth; remain in original state; gravity</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Earth's rotation</td>
<td>Earth's rotation</td>
<td></td>
</tr>
<tr>
<td>4</td>
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*: a difference between the student responses to the INTTES and to the interview