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A CASE STUDY OF SCIENCE CURRICULUM INTEGRATION:
EARTH SYSTEMS APPROACH

DISSERTATION

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

By
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* * * * *

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ABSTRACT

This case study investigates the Integrated Earth Systems Science (IESS) curriculum and instruction in a middle school. The purposes of this study are to: (1) explore one teacher's views on Earth Systems Education (ESE); (2) describe and document the characteristics of the IESS curriculum; (3) explore students' views about characteristics of the IESS curriculum and instruction; (4) investigate students' understandings related to ESE; and (5) compare IESS students' with a comparison group related to their self-reported knowledge, perceived significance, and primary information sources for Earth systems and environmental topics.

This study used a mixed methodology of qualitative and quantitative procedures. Data include observations; interviews with the teacher, Mr. Fox, and his eighth grade students; informal conversations; document analysis; field notes; and a student survey. The findings reveal that the curriculum emphasizes locally relevant topics, global concepts approached on a regional basis, and human interactions as a part of Earth systems.

Mr. Fox uses a constructivist approach to teach IESS. His primary teaching strategies are hands-on, activity-based, and project-based. Cooperative learning,
concept mapping, and science field trips are integral components of his instruction.

Student interviews indicate that they were positive about Mr. Fox's teaching strategies and assessment and found his strategies to beneficial to their understanding and connect classroom learning to the real world. However, their views on the use of concept maps for assessment were mixed.

The findings of the quantitative analysis indicate that self-reported knowledge and perceived significance mean scores for Mr. Fox's students were slightly higher than that of the comparison group for 13 Earth systems topics. Self-reported knowledge and significance scores related to global warming, pesticides in agriculture, and El Niño were significantly higher for Mr. Fox's students. Also, self-reported knowledge for concepts related to the value of Earth; interaction of water, land, air, and life; and cycles in nature were significantly higher for Mr. Fox's students. Additional findings indicate that a majority of Mr. Fox's students selected school as the primary information source for Earth systems and environmental topics, whereas the comparison students relied on both school and TV for their information.
Dedicated to my wife
I would like to express my sincere gratitude and thanks to the many individuals whose lives have been woven into the fabric of my academic journey. Though not all their names be mentioned in the short writing below, as I write this page I deeply appreciate their encouragement, guidance, and support.

First, I would like to thank my co-advisor, Dr. David L. Haury, for his constant support, understanding, and wonderful recommendations. Dr. Haury always encouraged me with warm smiles.

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CHAPTER I

INTRODUCTION

Over the last decade, one notable effort to improve science education is an integrated science approach within the science disciplines or with other disciplines; e.g., mathematics and/or technology (Berlin & White, 1998; DeBoer, 1991; Haury & McCann, 2000; H. Lee, 2000; McCormack, 1992; Mayer et al., 1992; Mayer & Fortner, 1995; Pang & Good, 2000). There is extensive support for integrated (or interdisciplinary) approaches to curriculum and instruction as evidenced by all of the national organizations' documents that advocate integrated approaches as a necessary component of national education reform (American Association for the Advancement of Science [AAAS], 1989, 1993, 1998; International Technology Education Association [ITEA], 1996, 2000; National Council of Teachers of Mathematics [NCTM], 1989, 1991, 1995, 2000; National Research Council [NRC], 1990, 1996; National Science Teachers Association [NSTA], 1992, 1997). For instance, Project 2061 (American Association for the Advancement of Science, 1989) emphasized that the traditional boundaries between disciplines should be softened and connected. As Fortner and Boyd (1995) observed, Scope, Sequence and
Coordination (SS&C; National Science Teachers Association, 1992) was "an effort of the National Science Teachers Association to outline a science curriculum for grades K-8 that integrated the disciplines and focused on major concepts that would be revisited at various grade levels in progressing degrees of complexity and scale" (p. 1). Its major focus was to coordinate the teaching of four school science disciplines, biology, chemistry, Earth science, and physics for grades 7-12.

The National Science Education Standards (National Research Council, 1996) provides guidelines for reform in science education and school science curriculum as well as details of science content standards. One changing emphasis of the standards is that previously educators were "treating science as a subject isolated from other school subjects" and now there is "more emphasis on connecting science to other school subjects, such as mathematics and social studies" (p. 224).

These education trends and reforms represent the desire for change in science education and the development of new science curriculum programs, frameworks, curriculum materials, and instructional activities. In addition, a variety of integrated science projects, models, or programs have influenced contemporary school education. One representative science education curriculum effort and project is Earth Systems Education (ESE). ESE is a wide-scale science education program that focuses on establishing integrated science programs using the Earth system as the unifying theme (Mayer & Fortner, 1995). According to Fortner and Boyd (1995), ESE takes its ideas and concepts from the vision of Earth Systems Science (Earth System Sciences Committee, 1988) and its educational approach to Earth systems
science from the National Aeronautics and Space Administration (NASA). ESE focuses on the use of Earth as a source of continuing high visibility and support for a K-12 integrated science curriculum. Its philosophy and approach to science content focus on planet Earth. ESE is based on all of Earth's subsystems, including the hydrosphere (water); lithosphere (land, sediments, and rocks); atmosphere (air); and biosphere (life) and their interactions and processes (Mayer, 1993a). According to Mayer et al. (1992), many attempts to integrate the science curriculum in the past have lacked a conceptual focus. Therefore, ESE is the new logical focus for an integration effort.

As evidence of dissemination of ESE, from 1990 to 1994, about 200 teachers became directly involved in the Earth Systems Education program. An estimated 7,000 additional teachers have been involved in short workshops (Mayer & Fortner, 1995). Schools in Colorado, Utah, Montana, Louisiana, Florida, and Alaska, as well as Ohio, use the Earth system approach for interdisciplinary science. In Ohio, ESE was implemented at the senior high school level in one central Ohio school system and at the middle or high school level in several others (e.g., Worthington High School, Dublin High School, Bexley Middle School). They have developed innovative Earth systems integrated science curricula using a framework based on a national reform effort. For example, Fortner, Pinnicks, Shay, Barrow, Jax, Steele, and Mayer (1992) reported that high school science teachers of Worthington, Ohio, integrated the ninth and tenth grade program into a new curriculum, Biological and
Earth Systems Science (BESS) course, which offered:

- relevance to students needs.
- interdisciplinary and collaborative experiences (the way real science operates).
- understandings (rather than bits and pieces).
- rigor (exploring, questioning, and making decisions).
- critical thinking (not just memorizing). (p. 33)

The Worthington team refined a vision of Earth Systems Education that provided a relevant context for students as a national curriculum model.

During 1999, the Biological Science Curriculum Study (BSCS) surveyed the offices of state science supervisors to determine the interest in and current status of integrated science programs at the high school level across the country (Biological Science Curriculum Study, 2000). The findings from this survey indicated that 31 states have offered integrated science, in which sciences at high school levels were taught in an integrated fashion. Among 31 states, each state offers the integrated science course to five different grade level bands: Only 9 grade (9 states, 29 %), grades 9-10 (15 states, 48.3 %), grades 9-11 (2 states, 6.5 %), grades 9-12 (4 states, 13 %), and grades 10-11 (1 state, 3.2 %). In addition, state science supervisors responded that their major concerns about integrated science at high school level are lack of curriculum materials, professional development needs, teacher resistance, assessments for integrated science, high school proficiency exam, and teacher
certification. Even though there are still a number of concerns, some kind of integrated science course has been taught in 31 states.

Biological Science Curriculum Study (2000) also found that “Earth systems” is used as a major theme of integrated science in many states. In the Utah science core curriculum, ninth grade integrated science focuses on the theme of “Earth systems.” The Utah State Office of Education requires Earth systems to be taught to all grades in the state. For example, the Ogden City School District requires Earth systems for all ninth graders. Earth, physical, space, and life science contents are integrated in a curriculum with two primary goals:

- Students will value and use science as a process of obtaining knowledge based on observable evidence.
- Students will develop an understanding of interactions and interdependence within and between Earth systems and changes in Earth systems over time. (pp. 105-106)

Through a variety of efforts at both the university and pre-college level sponsored by NASA and other agencies and groups, interest and activity has been evident in not only the United States, but also worldwide. Over the past several years, there has been considerable interest in Japan stimulated by the Earth science section of the Educational Research Division of Monbusho. A number of studies have been conducted on developing field teaching using an Earth systems science approach (Goto, 2002; Mayer, 1997; Mayer & Tokuyama, 2002). New Courses of Study in science were announced for the lower secondary schools in 2000 and the
Curriculum developers in both Taiwan and Korea are also interested in Earth Systems Education as a structure for the Earth science content of their national curricula (Mayer, 2002). Cyprus offers Earth Systems Education as a component of its new teacher education program at the graduate level. In 2000, the Earth as a System Project introduced ESE to secondary science education in Germany as a new approach for teaching sciences within a geoscientific framework (Hlawatsch, Bayrhuber, Euler, Hassenpflug, Hansen, Hildebrandt, Hoffmann, Lucius, & Siemer, 2002; Lang, 2002).

In summary, many states in the United States (more than 60%) have offered integrated science courses in their high schools (Biological Science Curriculum Study, 2000). Several countries have paid attention to ESE and the Earth systems approach to reform their science curriculum. Earth systems as a unifying theme of integrated science has become widely accepted and has considerably influenced the restructuring of science curriculum and curriculum development. NASA also continues to recommend the seminal document of ESE, Science is a Study of Earth (Mayer & Fortner, 1995) as the textbook for on-line courses in science education.

**Statement of the Problem**

Many recent studies and national documents recognize the urgent need for reform in science education and advocate an integrated (or interdisciplinary) approach. However, as Trefil and Hazen (1995) observed, appropriate integrated programs are not yet widely taught. Curriculum materials or other support material
(e.g., textbooks, instructional activities) are not readily available for schools wishing to integrate. Although Biological Science Curriculum Study (2000) survey results also indicated that around 60% of states currently offer an integrated science course in their high school, the states have many challenges to implementing integrated science programs (e.g., lack of curriculum materials, professional development needs, and assessment in integrated science).

According to Pang and Good (2000), one important problem is lack of documents evaluating the effectiveness of integrated approaches. They also suggested that more empirical studies concerning contextual difficulties in implementing integrated approaches and possible solution methods are needed for future research.

Despite many efforts to spread and implement ESE, there is very little research that investigates Integrated Earth Systems Science (IESS) as it is implemented in practice. What does the implementation of IESS teaching and learning look like? How does IESS curriculum and instruction influence students' learning, construction of knowledge, and understanding of science? Moreover, do students' statements and work reflect ideas of the Earth systems' curriculum and instruction? The lack of research related to these questions can be a major obstacle and an important challenge to the dissemination of ESE since the benefits and advantages of the Earth system approach are not clearly documented. In order to promote this integrated approach to curriculum and instruction, supporting documents based on research findings are needed.
Purposes of the Study

The purposes of this case study were to: (1) explore one experienced teacher’s views on the Earth Systems Education experiences; (2) describe and document the nature and characteristics of the Integrated Earth Systems Science (IESS) curriculum provided by the teacher; (3) explore students’ views about characteristics of the IESS curriculum and instruction; (4) investigate students’ understandings regarding the framework of ESE; and (5) compare IESS students’ self-reported knowledge, ascribed significance levels of Earth systems and environmental topics, and primary information source about the environmental topics with a comparison group.

Research Questions of the Study

The specific questions to be addressed in this study are:

1) What are the teacher’s views on ESE, the framework of ESE, constructivism, and other components of IESS curriculum and instruction?

2) What does the teacher perceive to be some of the benefits, barriers, or difficulties with teaching IESS?

3) What are the characteristics of IESS curriculum and instruction?

4) What are students’ views about the characteristics of the IESS curriculum, instruction, evaluation, instructional materials, field trips, and mini-projects?
5) What are students’ perceptions of the major concepts and themes within the ESE framework?

6) How do IESS students’ self-reported knowledge and perceived significance levels, and their primary information sources about Earth systems and environmental topics differ from those of a comparison group?

This study was conducted in Mr. Fox’s classroom and his field trip locations related to the IESS curriculum and instruction, with the researcher acting as a participant observer. Interpretation of data related to research questions 1, 4 and 5, was based on the Earth Systems Education Model that is guided by the Framework of Seven Earth Systems Understandings and developed by a core advisory group of scientists, teachers, and science educators (Fortner & Boyd, 1995; Mayer, 1991b; Mayer & Fortner, 1995). The framework was used to interpret IESS teaching and learning in this study. With respect to research questions 5 and 6, I employed a survey research method. A paper-and-pencil questionnaire was used to collect this quantitative data.

Significance of the Study

The significance of this study lies in the fact that it provides answers to the following questions: 1. What are the distinguishing features of Earth Systems Education in a school? and 2. How does an ESE teacher implement the integrated science curriculum? As this new integrated approach is important for science
education, this study will also contribute support for the IESS curriculum and
instruction that has produced a variety of instructional materials based on Earth
systems as a unifying theme.

There have been no empirical studies of the implementation of IESS in real
classroom contexts. Therefore, this study, which involves a study of a classroom
where IESS is taught, is expected to provide empirical qualitative, and quantitative
evidence about IESS. Specifically, this research is expected to inform the ESE
teacher by providing descriptive and analytical accounts of IESS teaching and
learning as an innovative integrated science curriculum, and by providing insight
into barriers, benefits and obstacles as well as ESE instructional strategies and
characteristics of the curriculum. Furthermore, observation and examination of the
classroom realities of implementing IESS are expected to provide insight and
empirical evidence to other science teachers who are interested in IESS, to
researchers, curriculum developers, teacher educators, and to school, state, and
government administrators.

Assumptions

Three assumptions frame this case study. The first assumption is that ESE in
science education can provide a new logical focus and conceptual framework for
developing integrated science curriculum. For example, the use of Earth and the
subsystems of air, land, water, and life as the context for the science content can be an important focus for implementing a locally relevant integrated curriculum (Mayer et al., 1992).

The second assumption is that ESE teaching strategies, materials and emphasis on the use of current technology in studying Earth have a positive impact on students’ science learning. Further, ESE helps students to develop their sense of stewardship and appreciation about Earth and our environment.

The third assumption is that the class’s role in this study requires no changes in the science curriculum, and no additional assignments given to the students. Furthermore, no significant changes are made in the routines established by the teacher, other than the presence of the researcher and a videotape recorder in the classrooms.

**Definition of Terms**

The purpose of this section is to define and clarify terms used in this study. Some of these terms mean different things to different people. The operational definitions shown here are meanings specific to this research.

*Integrated science.* A course of study in the sciences that draws on content and concepts from all of the major disciplines of science: Earth science (including space science), life science (biology), and physical science (chemistry and physics) (Biological Science Curriculum Study, 2000). In this ESE model, the goal is to teach
concepts from all of the science disciplines by using Earth systems as a unifying theme, but not necessarily to integrate all science disciplines in every lesson or every unit.

Interdisciplinary. With relation to curriculum, some individuals use the term interdisciplinary as a synonym for integrated. In this study, the term interdisciplinary is used for a course that brings together content from more widely separated discipline areas, such as science and social studies or science, language arts, and geography. This term does not refer to the relationship that is confined to disciplines within the science domain such as chemistry and biology (American Association for the Advancement of Science, 1993; Biological Science Curriculum Study, 2000).

Earth system. The Earth regarded as a unified system of interacting components, including core, mantle, lithosphere, oceans, atmosphere, cryosphere, and biosphere (Earth System Sciences Committee, 1988, p. 200).

Earth systems science. A holistic approach to the study of the Earth that stresses investigations of the interacting among the Earth's components in order to explain Earth dynamics, Earth evolution, and global change (Earth System Sciences Committee, 1988, p. 200).

System. A collection of things and processes (and often people) that interact to perform some function. The scientific idea of a system implies detailed attention to inputs and outputs and to interactions among the system components (American Association for the Advancement of Science, 1993, p. 262).
**Delimitations**

Due to the specific goals of this study, one limitation is that it involves only one school district and school in which only a relatively narrow range of socioeconomic conditions is represented. Even though many teachers at different schools currently teach IESS, this study confines itself to observe and interview the teachers and students at one specific middle school setting. Therefore, this purposive sampling procedure can decrease the generalizability of findings. However, my findings are confined to the specific participants and contexts because this study is a descriptive case study. For example, the students who participate in this study are selected only after permission is granted by their parents. Students who did not return a signed parental permission form did not participate in the study.

Naturalistic inquirers argue that the generalization of findings is impossible, since there are always differences in context from situation to situation, and even the single situation differs over time (Borland, 1990; Guba & Lincoln, 1989; Lincoln & Guba, 1985). For the purpose of this study, several variables are not considered in the synthesis such as the time of year compared to other times of the year; those students who do not get permission from their parents; and student race, religion, or age.
CHAPTER 2

REVIEW OF THE LITERATURE

In keeping with this study's goal to better understand the nature of implementing IESS in a natural context, the review of literature focuses on two major theoretical orientations of ESE (i.e., System theory and Constructivism), the ESE model, and research on ESE for providing the basic ideas of ESE. This literature review is organized into four sections:

- Section A: System Theory and System Approach in Science Education;
- Section B: Earth Systems Science;
- Section C: The Model of Earth Systems Education;
- Section D: Constructivism: Theoretical Orientation of Earth Systems Education.

Section A: System Theory and System Approach in Science Education

Over several decades, scientists, philosophers, and mathematicians have been working to construct a theoretical framework for unifying the many branches of the
scientific enterprise for science education. The product of this effort (system theory) is seen to provide a powerful framework for understanding both natural and the human-constructed world (Chen & Stroup, 1993). This system theory has provided a powerful framework in science and science education. For example, the Earth system presented by the Earth System Sciences Committee (1988) provides science educators with a conceptual approach to curriculum integration (Mayer, 1995). In this system approach, the Earth is regarded as a unified system of interacting components, including lithosphere, atmosphere, cryosphere, hydrosphere, and biosphere (Earth System Sciences Committee, 1988). The background of system theory, influence of system theory on science education, and a brief history of system theory in science education will be presented in the next section.

**System Theory**

As Blauberg, Sadovsky and Yudin (1977) observed, a German-Canadian biologist, Ludwig von Bertalanffy (1901-1972) was a creator of General System Theory (GST). His conceptual approach has had a wide impact on such diverse disciplines as biology, psychology, economics, etc. His system theory is an attempt to formulate common laws that apply to every scientific field. Heylighen and Joslyn (2001) states,

Bertalanffy was both reacting against reductionism and attempting to revive the unity of science. He emphasized that real systems are open to, and interact with, their environments, and that they can acquire qualitatively new properties through emergence, resulting in continual evolution. Rather than reducing an entity (e.g., the human body) to the
properties of its parts or elements (e.g., organs or cells), systems theory focuses on the arrangement of and relations between the parts which connect them into a whole (cf. holism). This particular organization determines a system, which is independent of the concrete substance of the elements (e.g., particles, cells, transistors, people, etc). Thus, the same concepts and principles of organization underlie the different disciplines (physics, biology, technology, sociology, etc.), providing a basis for their unification. (p. 1)

Furthermore, in his outline of the major aims of general system theory, we can find the implications for education (Chen & Stroup, 1993). His system theory provides a basis and unifying focus for integrated science education. His list of the major aims includes:

- There is a general tendency towards integration in the various sciences, natural and social.
- Such integration seems to be centered in a general theory of systems.
- Such theory may be an important means for aiming at exact theory in the nonphysical fields of science.
- Developing unifying principles running “vertically” through the universe of the individual sciences, this theory brings us nearer to the goal of the unity of science.
- This can lead to a much-needed integration in scientific education. (Bertalanffy, 1969, p. 38)

Heylighen and Joslyn (2001) describe the system theory as “the transdisciplinary study of the abstract organization of phenomena, independent of their substance, type, or spatial or temporal scale of existence. It investigates both the
principles common to all complex entities, and the (usually mathematical) models which can be used to describe them.” (p. 1) In addition, at the core of system theory are the notions that:

1. A “system” is an ensemble of interaction parts, the sum of which exhibits behavior not localized in its constituent parts. (That is, “the whole is more than the sum of the parts.”)

2. A system can be physical, biological, social, or symbolic; or it can be comprised of one or more these.

3. Change is seen as a transformation of the system in time, which, nevertheless, conserves its identity. Growth, steady state, and decay are major types of change.

4. Goal-directed behavior characterizes the changes observed in the state of the system. A system is seen to be actively organized in terms of the goal and, hence, can be understood to exhibit “reverse causality.”

5. “Feedback” is the mechanism that mediates between the goal and system behavior.

6. Time is a central variable in system theory. It provides a referent for the very idea of dynamics.

7. The “boundary” serves to delineate the system from the environment and any subsystems from the system as a whole.

8. System-environment interactions can be defined as the input and output of matter, information, and energy. The system can be open, closed, or semipermeable to the environment. (Chen & Stroup, 1993, pp. 448-449)

Influence of System Theory on Science Education

In building on the traditional science disciplines to study the Earth, the system approach has become widely accepted as a framework by science communities. Several documents also support the ‘system’ idea as a unifying theme
to understand science, and science education. Earth System Sciences Committee (1988) suggests that “maturation of traditional disciplines, a global view of the Earth from space, and the recognition of the human role in global change have combined to stimulate a new approach to Earth studies-Earth systems science. In this approach, the Earth system is studied as a related set of interacting processes, rather than as a collection of individual components” (p. 13). Furthermore, Mayer (1995) mentions that the Earth system can provide science educators with a conceptual approach to curriculum integration.

There has been support emanating from science education communities for increased emphasis on teaching and learning about system thinking (or system as a thematic idea) in science classrooms (Chen & Stroup, 1993; Fortner, 1991, 1992; Garigliano, 1975; Hill & Redden, 1985; Karplus & Randle, 1970; Karplus & Thier, 1969; Mayer, 1991a, 1993a, 1993b, 1995; Mayer & Armstrong, 1990; Mayer et al., 1992; Mayer & Kumano, 1999).

The Science Curriculum Improvement Study (SCIS) of the mid-1960s was among the first efforts to realize the potential of system thinking at the level of school curricula (Karplus & Randle, 1970; Karplus & Thier, 1969). SCIS curriculum tried to lead students to approach observation and analysis of natural phenomena by thinking of them as systems of interacting objects (Karplus & Thier, 1969). In the 1980s and 1990s, Science for All Americans (SFAA) of the American Association for the Advancement of Science (1989) recommended that all students should know about “systems” as a common theme. The Benchmarks for Science Literacy
(American Association for the Advancement of Science, 1993) suggests how student understanding of "systems" as a thematic idea should grow over the school years. As Mayer (1995) points out, the Benchmarks can be "an important tool for Earth systems educators as they locate more specific information for the construction of curricular models for their particular school districts" (p. 385).

Any collection of things that have some influence on one another can be thought of as a system. The things can be almost anything, including objects, organisms, machines, processes, ideas, numbers, or organizations. Thinking of a collection of things as a system draws our attention to what needs to be included among the parts to make sense of it, to how its parts interact with one another, and to how the system as a whole relates to other systems. Thinking in terms of systems implies that each part is fully understandable only in relation to the rest of the system...Any part of a system may itself be considered as a system-a subsystem-with its own internal parts and interactions. (American Association for the Advancement of Science, 1989, pp. 166-167)

In addition to SFAA and the Benchmarks, the National Science Education Standards (National Research Council, 1996) presents eight categories of content standards. Among eight standards, the standard for "unifying concepts and processes" includes the following conceptual and procedural schemes that integrate science disciplines and provide K-12 graders with powerful ideas to help them understand the natural world.

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Evolution and equilibrium
- Form and function
In the standards, "systems" as a unifying concept and process can provide students a big picture of scientific ideas for learning of scientific concepts and principles. Moreover, the idea of systems provides "a framework in which students can investigate the four major interacting components of the Earth system-geosphere (crust, mantle, and core), hydrosphere (water), atmosphere (air), and the biosphere (the realm of all living things)" (National Research Council, 1996, pp. 158-159). It is very clear that these national documents have supported the idea of system for science education, especially, for Earth and space science education.

As observed above, the system theory has influenced science education. Chen and Stroup (1993) emphasized several strengths of the system theory for science education.

- Toward integration: General system theory (GST) provides a set of powerful ideas students can use to integrate and structure their understanding in the disciplines of physical, life, engineering, and social science.

- Engaging Complexity: Complexity is the fundamental trait of the everyday environment in which the student lives. Traditional science education has avoided engaging complexity by promoting curricula built upon overly simplified activities and frameworks. GST provides the tools for actively engaging complexity. This offers the possibility of bridging the gap between the world of the learner and the world of science education.

- Understanding change: The world as it is experienced is dynamic. To ignore the centrality of change over time is to present a picture that is alienated from reality. Traditional science education has tended to focus on static and rote sequences. The system theory offers the intellectual tools for learners to build understanding based on dynamics. (p. 448)
Finally, they suggest that the system theory "takes up the challenge of creating a powerful framework for discipline integration. As such it stands to provide a coherent alternative to the current pastiche of reform efforts based on vague or underdefined notions of what interdisciplinary science curricula might look like" (p. 457). In addition, system oriented science methods and content in school science curricula can effectively help teachers teach about basic physical, chemical and biological processes that act within Earth systems. It can demonstrate how basic processes operate within systems and show how systems are changed by human interventions. Using a system approach as a conceptual approach to the organization of curricula can replace many current interdisciplinary approaches to science curricula or curricula integration (Mayer & Kumano, 1999).

Section B: Earth Systems Science

Over the past several decades, as science and technology have developed dramatically, there have been tremendous advances in the understanding of planet Earth, its processes, and interaction with subsystems. For instance, satellite images and data have led to a reawakening of the sciences and reinterpretation of planet Earth (Mackenzie, 1998). Due to the development of science and technology, the peoples of world are no longer passive spectators to the drama of Earth change and evolution. Through our economic and technological activity, people as a part of Earth system are contributing to significant global changes on the Earth. The
challenge of global change has become an additional important motivation for study of the Earth. The Earth System Sciences Committee (ESSC) also identified the following three motivations for the Earth system approach: Science for practical benefits, global change, and the Earth as a planet (Earth System Sciences Committee, 1988).

Based on such background and motivations, these big movements and understanding for science and science education are documented in the “Bretherton Report,” developed by a committee of scientists representing various government agencies with Earth science research mandates (Earth System Sciences Committee, 1988). This reconceptualization of the processes and goals for study of planet Earth has been termed the discipline of “Earth Systems Science (ESS).”

Then, what is Earth systems science?

ESS takes the main components of planet Earth-the atmosphere, oceans, freshwater, rocks, soils, and biosphere-and seeks to understand major patterns and processes in their dynamics. To do this we need to study not only the processes that go on within each component, but also interactions between these components. It is the need to study and understand these between-component interactions that defines ESS as a discipline in its own right. (Lawton, 2001, p. 1965)

Johnson, Ruzek, and Kalb (1997) state, “The Earth system science concept fosters synthesis and the development of a holistic model in which disciplinary process and action lead to synergistic interdisciplinary relevance” (p. 688). Further, Earth System Science Online (2001) describes Earth systems science as a view of the Earth as a synergistic physical system of interrelated phenomena, governed by
complex processes involving the geosphere, atmosphere, hydrosphere and biosphere. Fundamental to the Earth systems science approach is the need to emphasize relevant interactions of chemical, physical, biological and dynamical processes that extend over spatial scales from microns to the size of planetary orbits, and over time scales of milliseconds to billions of years.

Finally, the concept of the Earth as a system, since that is a subject of investigation of all science disciplines, has been applied to a new integrated science model, Earth Systems Education (ESE). Earth systems science and the concept of Earth systems are currently used to conceptually organize several secondary school science curricula (Jax, 1995; Mayer & Fortner, 1995). In the next section, I will discuss the model of Earth Systems Education.

Section C: The Model of Earth Systems Education

*Earth Systems Education*

Earth Systems Education (ESE) can be defined as the wide-scale science education program which studies the planet Earth as a system of many interacting subsystems and focuses on the changes and evolution within and between subsystems of water (hydrosphere), land (lithosphere), air (atmosphere), ice (cryosphere), and life (biosphere). (See Figure 2.1.) In other words, one of the important features of ESE for science curriculum restructuring is an emphasis on the use of Earth and Earth’s subsystems as the context for the content to be covered (Mayer et al., 1992).
Earth Systems Education focuses on the subject of all four traditional sciences (i.e., Biology, Earth Science, Physics, and Chemistry) and planet Earth, placing the Earth at the center of the new science curriculum (Mayer & Fortner, 1995). In addition to traditional school sciences, ESE partly includes the ideas and
content of environmental education. In other words, stewardship and appreciation are major differences between ESE and previous science curriculum. In the ESE model,

Students can develop an appreciation not only of Earth itself, but of the length of time it has existed and how and why it has changed over time. The ways in which the Earth systems have changed and why they have changed lead us to an understanding of how they may continue to change in the future. This is very important in developing a sense of stewardship for the Earth. (Jax, 1995, p. 28)

Fortner (1999a) explains that the relevant ESE components are derived from the traditional sciences: ESE primarily focuses on Biology and Earth science, then adds Physical sciences (Physics and Chemistry) as they relate to the Earth. Furthermore, an environmental education component is partly included in the domains of ESE (see Figure 2.2).

Figure 2.2: ESE: Relevant components of traditional science disciplines.
According to Fortner and Boyd (1995), ESE takes its name and ideas from NASA's vision of Earth systems science that was developed by the Earth System Sciences Committee (1986, 1988). The ESE model is a K-12 educational effort and approach to Earth systems science. The next section begins with the background of ESE followed by the history and framework of ESE that guided this study.

**Background of Earth Systems Education**

In the mid-1980s, there had been two major science education reform efforts: Project 2061 of the American Association for the Advancement of Science (AAAS), and Scope, Sequence, and Coordination (SS&C) of the National Science Teachers Association (NSTA). Project 2061 is a long-range and multi-phase effort to reform K-12 education in the natural and social sciences, mathematics, and technology. Begun in 1985, the project is designed to help the nation achieve scientific literacy; to help local, state, and national educators redesign curriculum in these areas and ensure its success; and to develop the basis for a reconceptualization of the content of the K-12 science curriculum (American Association for the Advancement of Science, 1989; Mayer et al., 1992).

The NSTA-initiated project of Scope, Sequence, and Coordination (SS&C) also represented a major reform effort of science at the secondary level. This project advocates sequenced, well-coordinated instruction in all the sciences that all students study every year for 7 years so that students acquire a greater depth of understanding in science. The project recommends coordination of the science disciplines by the
use of topics and processes that they share, and a spiraling of topics in successive years and in increasingly more abstract contexts for grades 6 through 12 (Jax, 1995; Mayer & Fortner, 1995; Pearsall, 1992).

As Mayer and Fortner (1995) observe, these two projects supported common reform elements in that they both:

- are broad-based, multi-year initiatives to reform science education.
- emphasize how students actually learn and sequence instruction accordingly.
- advocate science literacy for all students and promote the success of minorities, females, and groups, like the disabled, alienated by traditional science education.
- do not perpetuate the idea that only intellectually elite students are capable of learning and enjoying science.
- question the structure and content of traditional science courses and propose carefully considered alternatives.
- subscribe to the notion that depth of understanding is more critical than broad, superficial coverage of science topics.
- invite variations on curriculum design that retain definitive principles of the project.
- have six sites around the country—though each defines a site differently—developing alternative approaches to teaching and learning.
- involve teachers in the design of curricula and show concern for the professional development of teachers.
- involve university programs, scientific societies, and education associations.
involve parents, school administrators, science supervisors, and consultants.

- receive funding from the National Science Foundation.
- emphasize life-long learning. (p. 48)

These two projects barely attend to the nature of science and the planet Earth.

As the past curriculum restructuring efforts have ignored the Earth Science content areas, new reform movements also seem to fail to reflect a central role for planet Earth as core content of science curriculum (Mayer et al., 1992; Mayer, 1995). Therefore, in 1987, the Earth System Sciences Committee (ESSC), in a report to Congress and the Administration, proposed an integrated science model for research into the problems and characteristics of the Earth system (Earth System Sciences Committee, 1988). The report was used subsequently in a conference of geoscientists and educators organized under the support of the American Geological Institute (AGI), National Science Teachers Association (NSTA), and National Science Foundation (NSF) that took place in Washington, DC in 1988. The results of this conference (Mayer & Armstrong, 1990) formed the basis for a series of efforts in curriculum restructure for Earth science education at the pre-college level. As Mayer and Armstrong (1990) state, conference participants developed the following four goals and ten concepts of ESE that were a prerequisite for an evolving vision of planet Earth to provide a basis for an adequate representation of planet Earth in contemporary curriculum efforts.
Four Goals of ESE:

1. Scientific thought: Each learner will be able to understand the nature of scientific inquiry using the historical, descriptive, and experimental processes of the Earth sciences.

2. Knowledge: Each learner will be able to describe and explain Earth processes and features and anticipate changes in them.

3. Stewardship: Each learner will be able to respond in an informed way to environmental and resource issues.

4. Appreciation: Each learner will be able to develop an aesthetic appreciation of the Earth.

Ten Concepts of ESE:

1. The Earth system is a small part of a solar system within the vast universe.

2. The Earth system is comprised of the interacting subsystems of water, land, ice, air, and life.

3. The Earth’s subsystems (water, land, ice, air, and life) are continuously evolving changing and interacting through natural processes and cycles.

4. The Earth’s natural processes take place over periods of time from billions of years to fractions of seconds.

5. Many parts of the Earth’s subsystems are limited and vulnerable to overuse, misuse, or change resulting from human activity. Examples of such resources are fossil fuels, minerals, fresh water, soils, flora and fauna.

6. The better we understand the subsystems, the better we can manage our resources. Humans use Earth resources such as mineral and water.

7. Human activities, both conscious and inadvertent, impact Earth subsystems.
8. A better understanding of the subsystems stimulates greater aesthetic appreciation.

9. The development of technology has increased and will continue to increase our ability to understand Earth.

10. Earth scientists are people who study the origin, processes, and evolution of Earth's subsystems; they use their specialized understanding to identify resources and estimate the likelihood of future events. (pp. 160-163)

These goals and concepts were not only clearly and frequently identified as precursor developments and efforts, but were also used in developing the framework of the seven Earth Systems Education Understandings (see Table 2.3). This new focus and innovative reform effort for science curriculum, called Earth Systems Education (ESE), emerged on this basis.

Earth Systems Education provides

A framework for developing a locally relevant curriculum that meets the broad needs of students, it attends to the concerns mentioned in national curriculum development projects, and it allows for teachers to be the primary agents of change. This is what differentiates it from SS&C and Project 2061. (Jax, 1995, p. 30).

As can be seen in Table 2.1, other comparisons among science education reform efforts (e.g., Project 2061; Scope, Sequence and Coordination; Earth Systems Education; and National Science Education Standards) are presented in a format suggested by the work of Jax (1995) and Mayer and Fortner (1995).
<table>
<thead>
<tr>
<th>Project 2061</th>
<th>Scope, Sequence and Coordination</th>
<th>Earth Systems Education</th>
<th>National Science Education Standards</th>
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<tbody>
<tr>
<td>Defines Project 2061 effort in terms of the learning goals specified by <em>Science for All Americans</em> (SFAA). Sequencing and spacing are considerations but not definitions.</td>
<td>Defines a SS&amp;C project in terms of developmental sequencing of topics and their spacing and their repetition over several years.</td>
<td>Defines PLESE project and grassroots efforts. Appropriate sequencing and spacing are important.</td>
<td>Defines a National Committee on Science Education Standards and Assessment (NCSESA) effort and project of National Research Council (NRC). Sequencing and spacing are important. Not a national curriculum.</td>
</tr>
<tr>
<td>Focuses on K-12 curricula with specific benchmarks for science literacy at grades 2, 5, 8 and 12 that analyze and sequence the goals of SFAA and their interconnections.</td>
<td>Focuses on middle and high school science curricula. Recognizes that older students retain information from elementary school.</td>
<td>Focuses on K-16 curricula emphasizing locally relevant topics at the beginning, leading to a global perspective, and the use of appropriate materials from many sources and ones developed locally.</td>
<td>Is not a curriculum, mandate, or policy. Provides criteria that people at the local, state, and national levels can use to judge whether particular actions will serve the vision of a scientifically literate society.</td>
</tr>
</tbody>
</table>

(continues)

Table 2.1: Comparisons of Project 2061; Scope, Sequence and Coordination; Earth Systems Education; and National Science Education Standards.
<table>
<thead>
<tr>
<th>Project 2061</th>
<th>Scope, Sequence and Coordination</th>
<th>Earth Systems Education</th>
<th>National Science Education Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes all natural and social sciences, math and technology.</td>
<td>Includes all the natural sciences with their applications to technology.</td>
<td>Includes all natural and social sciences, math and technology.</td>
<td>Includes the following content standards: Unifying Concepts and Processes; Inquiry; Physical Science; Life Science; Earth and Space Science; Science and Technology; Science in Personal and Social Perspectives; and History and Nature of Science.</td>
</tr>
<tr>
<td>Recognizes the interdependence of the science disciplines and integrates or makes curriculum connections among the science disciplines and with the arts and humanities.</td>
<td>Recognizes the interdependence of the science disciplines and integrates them in middle school. Coordinates, but does not integrate the separate disciplines at the high school level.</td>
<td>Recognizes the interdependence of the science disciplines and integrates or makes curriculum connections among the science disciplines and with the arts and humanities.</td>
<td>Recognizes the interdependence of the science disciplines and integrates or makes curriculum connections among the science disciplines and with the other school subjects.</td>
</tr>
<tr>
<td>Proposes long-term reform of the entire K-12 system through blueprints on teacher education, assessment, policy, and other issues.</td>
<td>Is relatively short-term- a preliminary restructuring designed to induce a long-term change process.</td>
<td>Proposes long-term reform of grades K-16 through grassroots efforts using adaptation of materials and use of innovative pedagogy.</td>
<td>Provides a coherent vision and criteria of science education that will make scientific literacy for all students.</td>
</tr>
</tbody>
</table>

(continues)
Table 2.1 (continued)

<table>
<thead>
<tr>
<th>Project 2061</th>
<th>Scope, Sequence and Coordination</th>
<th>Earth Systems Education</th>
<th>National Science Education Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will provide alternative models for restructuring curriculum; in parallel arrangement, with little overlap among subjects; integrated around issues or phenomena; or in a mosaic, bound by a variety of organizing principles.</td>
<td>Will restructure curriculum so that students study a science subject area several hours per week every year in grades 6-12 (spacing) or the concepts of science over several years at progressively higher levels of abstraction (sequencing).</td>
<td>Provides a Framework of Seven Essential Understandings about Earth to guide restructure. A local focus is emphasized using local issues and topics as organizing themes. Examples of developed curricula are provided.</td>
<td>Provides criteria for 1) judgments regarding programs, teaching, assessment, policies; 2) identifying content; 3) emphasizing understanding; 4) linking content, teaching and assessment; and 5) call for systemic change.</td>
</tr>
<tr>
<td>Designs a coordinated set of reform tools-the basic components of curricula with alternative approaches to teaching and learning-for school districts to develop their own curricula.</td>
<td>Identifies instructional materials that can be taught over a 7 year-period. These materials will be used by schools to replicate their own curricula.</td>
<td>Identifies a set of reform tools-the basic components of curricula using the framework. Includes new approaches to teaching and learning. School districts develop their own curricula.</td>
<td>Offers a vision of what it means to be scientifically literate. The standards can be used as measures to judge the quality of current science education and criteria to design school science programs. Challenges for teachers, administrators, and the community.</td>
</tr>
</tbody>
</table>
History of Earth Systems Education

In addition to two national efforts to restructure school science education that existed in the early '90s (e.g., Project 2061, and SS&C), Mayer (1993a) states that a third effort was the Earth Systems Education. Earth Systems Education (ESE) is a curriculum restructuring project centered at The Ohio State University (OSU) and the University of Northern Colorado. In 1990, the Teacher Enhancement Program of the National Science Foundation awarded a grant to The Ohio State University for a "Program for Leadership in Earth Systems Education" (PLESE). The four-year PLESE project began in the summer of 1990. The major objective of PLESE was "to infuse more content regarding the modern understanding of planet Earth into the nation's K-12 science curricula" (Mayer et al., 1992, p. 7). In order to prepare for PLESE, the PLESE planning committee was organized in May 1990 to develop a conceptual framework on the basis of the preliminary framework of four goals and ten concepts. As presented in Table 2.1, preliminary works included the analysis of the Project 2061 report for content related to the Earth systems, and the development of a "Framework for Earth Systems Education" consisting of seven understandings (Mayer, 1991b; Mayer et al., 1992).

During the first summer for a three week session, scientists led sessions with the teams to relate their research interests in the Earth system to the teachers. Teams consisting of elementary, middle and high school teachers from the Great Lakes States were able to review exemplary curriculum materials about the Earth system, and were required to produce a thematic unit about a part of the Earth system.
relevant to their geographic area with suggestions of the materials that could be used and infused into teachers' existing curriculum. After the workshop ended, teams were expected to disseminate the new unifying theme, Earth system, and to spread what they had done through workshops given in districts or at local, regional and national conferences. In some schools, an entire science curriculum was restructured around an Earth system approach (Jax, 1995).

In the second (1991) and third (1992) year sessions, teams from eastern states went to The Ohio State University, whereas teams from western states went to the University of Northern Colorado for the Earth system institutes. During the final summer (1993) of PLESE, many participants from the previous institutes were invited to the University of Northern Colorado to begin the development of the resource guide (Jax, 1995; Mayer & Fortner, 1995). Jax (1995) stated,

What was unique about PLESE was that the teachers were given the control, the resources, and the expert help to develop their own curricula without having specific content dictated to them. They used the ESE framework as a guide. The result was a set of curricula that were grass-roots in origin and were locally relevant for each team. Teachers explored such different teaching methods as cooperative learning, alternative assessment and new technology useful in the classroom. (p. 29)

According to Mayer and Fortner (1995), about 200 teachers became directly involved in the program through three-week long workshops conducted at The Ohio State University and at the University of Northern Colorado during four years. Teacher teams were required to teach others about ESE following their science
experience. An estimated 7,000 additional teachers have been involved in short workshops conducted by the teacher participants and staff of this effort.

Before this PLESE project finished, the first International Conference on Geoscience Education and Training was held in Southampton, England, in April 1993. The primary focus of the first conference was the state of geoscience education throughout the world (Stow & McCall, 1993). In addition, the second International Conference on Geoscience Education was held in 1997 on the campus of the University of Hawaii - Hilo. It was attended by nearly 240 participants, representing 25 countries. As Fortner and Mayer (1998) described, the Second International Conference on Geoscience Education chose “Learning about the Earth as a System” as a main theme because

it emphasizes the importance of reexamining the teaching and learning of traditional Earth Science in the context of the many environmental issues facing the planet ... It is imperative that students at all grade levels and from all cultures have an understanding of how the Earth works. (p. 4)

Moreover, the third international conference was held at the University of New South Wales, Sydney, Australia. The central theme was “dedicated to teaching and learning” that highlights the concept that while we may be teaching geoscience, we can all learn from each others’ experiences and practices based on the Earth system approach (Clark, 2000). Further, a variety of curriculum materials illustrating the
Earth system approaches and aspects have been developed and used for schools.

Table 2.2 summarizes a brief history of ESE and major grant projects funded by national organizations and institutes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Content (or Product)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1994</td>
<td>PLESE project (Sponsor: NSF).</td>
</tr>
<tr>
<td>1995</td>
<td>Science is a Study of Earth – A Resource Guide for Earth Systems Education (Sponsors: NSF and The Ohio State University).</td>
</tr>
<tr>
<td>1996-1999</td>
<td>Internet-Linked Instructional Materials: Earth system approach (Sponsor: Ohio Sea Grant).</td>
</tr>
<tr>
<td>1997</td>
<td>2nd ICGE, Hawaii, USA (Theme: Learning About the Earth as a System).</td>
</tr>
<tr>
<td>1999</td>
<td>Dr. Rosanne W. Fortner developed and taught new graduate course, NR 814 Earth Systems Education.</td>
</tr>
<tr>
<td>2000</td>
<td>3rd ICGE, Sydney, Australia (Theme: Dedicated to Teaching and Learning).</td>
</tr>
</tbody>
</table>

Table 2.2: Brief history of ESE and major grant projects.

**Framework of Earth Systems Education**

As mentioned previously, the development of the framework for ESE, started in 1988 with the Washington conference of educators and scientists, was modified by PLESE advisors, and culminated in a shortened list of 7 understandings that represented the fundamental outcomes of good science education for K-12. The 7
understandings framework provided a basis for PLESE teams to construct resource
guides and to select teaching materials for use in infusing Earth systems concepts
into the development of integrated science curricula (Mayer, 1991b) and continue to
provide structure for Earth systems teaching (see Table 2.3).

The first understanding is one of the major differences from the usual science
frameworks. This understanding emphasizes an appreciation of the Earth and
stewardship, and the inclusion of a broader knowledge of the nature of the science
process (Mayer & Fortner, 1995). With respect to this understanding, science
teachers need to provide “a firm foundation for the development of a system of
values that honors the enduring spirit of humankind and that recognizes its
dependence upon the esthetic qualities of planet Earth” (Mayer, 1989, p. 25). It is
also related to learning an aesthetic appreciation of the planet in art, literature, and
music (Yasso, 1991).

The second understanding emphasizes stewardship regarding environmental
issues, problems, and the use of natural resources. As Fortner (1991) indicates, this
understanding reminds us that all people are contributing to global environmental
problems. As a science teacher, enabling students to make right decisions and act on
them is a notable means of generating a personal commitment to action for a better
environment and a good planet.

The substance of the next four understandings are that “a developing concern
for conserving the economic and aesthetic resources of our planet leads naturally into
a desire to understand how the various subsystems function and how we study those
subsystems” (Mayer et al., 1992, p. 8). For instance, the third understanding emphasizes a variety of scientific methods and technology to study and solve problems in the Earth systems. The fifth understanding focuses on the great age of the Earth and the fact that its subsystems are constantly evolving (Jax, 1991). Furthermore, the last understanding deals with hobbies and careers in science relating Earth to systems. Early interest in the relevance of Earth systems can lead to rewarding careers.

Framework of the Seven Earth Systems Understandings

Understanding #1: Earth is unique, a planet of rare beauty and great value.
- The beauty and value of Earth are expressed by and for people through literature and the arts.
- Human's appreciation of planet Earth is enhanced by a better understanding of its subsystems.
- Humans manifest their appreciation through their responsible behavior and stewardship of its subsystems.

Understanding #2: Human activities, collective and individual, conscious and inadvertent, affect planet Earth.
- Earth is vulnerable, and its resources are limited and susceptible to overuse or misuse.
- Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.
- When considering the use of natural resources, humans first need to rethink their life styles, then reduce consumption, then reuse and recycle.
- By-products of industrialization pollute the air, land, and water, and the effects may be global as well as near the source.
- The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.

(continues)

Table 2.3: Framework for Earth Systems Education.
Understanding #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
- Biologists, chemists, and physicists, as well as scientists from the Earth and space science disciplines, use a variety of methods in their study of Earth systems.
- Direct observation, simple tools, and modern technology are used to create, test and modify models and theories that represent, explain, and predict changes in the Earth system.
- Historical, descriptive, and empirical studies are important methods of learning about Earth and space.
- Scientific study may lead to technological advances.
- Regardless of sophistication, technology cannot be expected to solve all of our problems.
- The use of technology may have benefits as well as unintended side effects.

Understanding #4: The Earth system is composed of interacting subsystems of water, rock, ice, air, and life.
- The subsystems are continuously changing through natural processes and cycles.
- Forces, motions and energy transformations drive the interactions within and between the subsystems.
- The Sun is the major external source of energy that drives most system and subsystem interactions at or near the Earth's surface.
- Each component of the Earth system has characteristic properties, structure, and composition that may be changed by interactions of subsystems.
- Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface. Weathering, erosion, and deposition continuously reshape the surface of the Earth.
- The presence of life affects the characteristics of other systems.

Understanding #5: Planet Earth is more than 4 billion years old and its subsystems are continually evolving.
- Earth's cycles and natural processes take place over time intervals ranging from fractions of seconds to billions of years.
- Materials making up planet Earth have been recycled many times.
- Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
- Evolution is a theory that explains how life has changed through time.

(continues)
Table 2.3 (continued)

**Understanding #6**: Earth is a small subsystem of a solar system within the vast and ancient universe.

- All material in the universe, including living organisms, appears to be composed of the same elements and to behave according to the same physical principles.
- All bodies in space, including Earth, are influenced by forces acting throughout the Solar System and the universe.
- Nine planets, including Earth, revolve around the sun in nearly circular orbits.
- Earth is a small planet, third from the Sun in the only system of planets definitely known to exist.
- The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes.
- The rotation of Earth on its axis determines day and night.

**Understanding #7**: There are many people with careers that involve study of Earth's origin, processes, and evolution.

- Teachers, scientists, and technicians who study Earth are employed by businesses, industries, government agencies, public and private institutions, and as independent contractors.
- Careers in the sciences that study Earth may include sample and data collection in the field and analyses and experiments in the laboratory.
- Scientists from many cultures throughout the world cooperate and collaborate using oral, written, and electronic means of communication.
- Some scientists and technicians who study Earth use their specialized understanding to locate resources or predict changes in Earth systems.
- Many people pursue avocations related to planet Earth processes and materials.


**Research on Earth Systems Education**

There is only one research study directly related to Earth Systems Education.

Jax (1995) examined the process and the factors that influenced the initiation and
implementation of an Earth systems integrated high school curriculum. He analyzed interviews, documents, and a student survey to describe the process the teachers went through, factors that influenced the process, the nature of the curriculum, and perceptions students had of the goals of the curriculum. According to this study, problems the teachers encountered in implementing this new integrated curriculum included: not having enough time to find and develop resources and solve problems; lacking proficiency in using the new technology, cooperative learning and alternative assessment techniques; having very limited in-service opportunities for developing new skills; and encountering some community resistance. However, teachers, given the resources, time, motivation, and control, can develop a curriculum that is effective in being integrated, evolutionary, innovative and relevant for students. Teachers encounter problems in such a process, but are able to manage them if they are prepared (Jax, 1995).

Section D: Constructivism: Theoretical Orientation of Earth Systems Education

Constructivism has been the most significant educational theory based on cognitive science theory. Over the past decade, educators in a variety of fields have elaborated on constructivism as a theory of teaching and learning, and a research paradigm (Matthews, 1994; Tobin & Tippins, 1993). In recent studies, Piaget and Ausubel are described as pioneers who contributed to the development of constructivist ideas. Piaget (1929, 1930, 1964, 1974, 1977) described how children
used their own understanding of nature to interpret natural phenomena. He also emphasized that the growth of knowledge was the result of individual constructions made by the learner. Often, Piaget is regarded as the father of modern constructivism (Brown, 1998; Crowther, 1999; Popkewitz, 1998; Wadsworth, 1989).

Similar constructivist ideas can be identified from Ausubel's studies (1960, 1962, 1963, 1968). Ausubel (1968) said, "the most important single factor influencing learning is what the learner already knows" (p. vi). He also mentioned that "the learner is able effectively to exploit his existing knowledge as an ideational and organizational matrix for the incorporation, understanding, and fixation of large bodies of new ideas" (p. 58). Furthermore, Popkewitz (1998) described that current constructivist's pedagogies could be traced from the writing of both the Russian psychologist Vygotsky and Piaget in the early 20th century.

As many famous philosophers and educators have proposed constructivist ideas or presented similar thoughts, constructivism has been the most significant trend and research topic in science education focusing on the relationship between how teachers teach and how learners learn. Fosnot (1996) indicated that most recent educational reforms advocated by national professional groups are based on constructivism. For example, these constructivist ideas are applied to two current national standards: the National Science Education Standards (National Research Council, 1996) and the Principles and Standards for School Mathematics (National Council of Teachers of Mathematics, 2000).
Learning is an active process by which students individually and collaboratively achieve understanding. Effective teaching requires that teachers know what students of certain ages are likely to know, understand, and be able to do; what they will learn quickly; and what will be a struggle. (National Research Council, 1996, p. 62)

Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well... Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge. (National Council of Teachers of Mathematics, 2000, pp. 370-371)

Similarly, in an Earth systems classroom, teaching strategies and approaches are very compatible with constructivist ideas. The principles and ideas of constructivism have had a great influence on the nature of students’ IESS learning and educators’ decisions related to IESS teaching (Mayer, 1993a; Mayer & Fortner, 1995). Evidence of constructivism used as a theoretical background and teaching strategies for ESE will be reviewed in the next section.

**Definition of Constructivism**

As constructivism becomes more popular in a variety of areas, the definition and terms are described with slightly different meanings, depending on pedagogical, psychological, or philosophical contexts (Bettencourt, 1993). As Fosnot (1996) defined,

Constructivism is a theory about knowledge and learning; it describes both what “knowing” is and how one “comes to know.” Based on work in psychology, philosophy, and anthropology, the theory
describes knowledge as temporary, developmental, nonobjective, internally constructed, and socially and culturally mediated. Learning from this perspective is viewed as a self-regulatory process of struggling with the conflict between existing personal models of the world and discrepant new insights, constructing new representations and models of reality as a human meaning-making venture with culturally developed tools and symbols, and further negotiating such meaning through cooperative social activity, discourse, and debate. (p. ix)

According to Bently and Watts (1994),

Constructivism is a philosophy and a psychology about the way people make sense of the world. The central point is that people are always intellectually active-they do not learn passively, but go out of their way to try to make some meaning in what is taking place in their environment. Our constructions of life are conditioned and constrained by our experiences and this means that—since we all have different experiences—we are all likely to have different perceptions about ideas, actions, behaviors, incidents, situations, tasks, feelings, and so on. (p. 8)

In constructivism, learners' pre-existing conceptual structure, knowledge, and belief are used as the basis for understanding the environment and achieving higher levels of knowledge. Constructivists consider that knowledge is actively constructed by learners through interaction with physical phenomena and interpersonal exchanges (Bently & Watts, 1994; Scruggs & Mastropieri, 1994; Watts, Jofili, & Bezerra, 1997).

ESE clearly holds constructivist perspectives regarding teaching and learning. For instance, Earth Systems Education efforts take a constructivist approach to learning both in PLESE workshops conducted by the staff and in the curriculum
restructuring efforts (Mayer, 1993a; Mayer et al., 1992). ESE philosophy and approaches to teaching and learning rest on the assumption that knowledge is constructed by learners as they attempt to make sense of their experiences. Learners are actively seeking meaning based on their prior knowledge.

Social Interaction (Cooperative Learning)

There has been increased interest in the social-cultural perspectives of cognition. Many educators have realized that learning is a complex social process that goes beyond mere transmission of knowledge, and have paid attention to the significance of the social environment (Clements & Battista, 1990; Jones, Rua, & Carter, 1998; Klein & Merritt, 1994; Yager, 1991).

Brooks and Brooks (1999) state the importance of social discourse as a way of knowing and understanding.

One very powerful way students come to change or reinforce conceptions is through social discourse. Having an opportunity to present one’s own ideas, as well as being permitted to hear and reflect on the ideas of others, is an empowering experience. (p. 108)

Woolfolk (1998) also describes the significance of social interactions and experiences for constructing knowledge. Woolfolk states, “Knowledge is constructed based on social interactions and experience. Knowledge reflects the outside world as filtered through and influenced by culture, language, beliefs, interactions with others, direct teaching, and modeling” (p. 279).
Cooperative and collaborative learning are productive constructivist strategies because of the importance of social interaction. Students are encouraged to work in groups and need to be involved in productive group interactions during the learning process (Brooks & Brooks, 1999; Johnson & Johnson, 1999; Johnson, Johnson, & Holubec, 1994; Klein & Merritt, 1994). Bentley and Watts (1994) describe five main tenets of classroom constructivism. Their fourth tenet is “learning is not just listing and writing. Group work and collaborative learning are examples of techniques which play upon ideas of active learning” (p. 11).

In ESE classrooms, cooperative learning as one major focus of ESE teaching, places students in groups where they work to solve a problem or investigation. Most ESE activities are organized for cooperative learning, and have links to the National Science Education Standards and Benchmarks. For example, the Earth Systems-Education Activities for Great Lakes Schools (ES-EAGLS) are designed to take a concept or idea from the existing school curriculum and use cooperative learning approaches and materials appropriate for students in middle and high school. When the teachers use any activities in the ES-EAGLS, their students can be grouped for cooperative learning to answer various kinds of important Earth systems questions (Fortner, 2002).

ESE also recommends the use of several different types of cooperative learning strategies in the science classroom, including Jigsaw II and Co-op Co-op. For instance, Jigsaw was developed by Aronson (1979), and Jigsaw II was further promoted by Slavin (1987). The jigsaw approach as one form of cooperative learning
is "a method of assembling a body of information from its diverse pieces, like a jigsaw puzzle. Members of groups acquire and hold information and contribute their pieces at an appropriate time in the assembly process" (Fortner, 1999b, p. 261). The idea behind this type of cooperative learning is for a learner to become an expert on one topic or concept and teach it to others.

The other type of cooperative learning is Co-op Co-op developed by Kagan (1985). There are five basic steps in this cooperative learning strategy: Student-centered discussion, team selection, topic selection, team presentations, and evaluation. The Co-op Co-op provides students a great amount of independence in choosing the topic and teams. Students also learn leadership skills and are responsible for making decisions for themselves (Mayer & Fortner, 1995; Mayer, Fortner, & Hoyt, 1995).

**Meaningful Learning**

Ausubel (1960, 1962, 1963) introduced the concept of meaningful learning, which focuses on the importance of organized guided exposition in the process of guiding the learner to construct his/her knowledge. If information can be meaningfully organized by the teacher, the learning process is more efficient for students. Meaningful learning is regarded as one of key elements of constructivist learning. Dunn and Larson (1990) mention that students can obtain valuable and meaningful experience throughout learner-centered instruction.
Children involved in active exploration learn that they can influence their environment. They eagerly seek answers to real problems they pose, building and testing theories, creating, and organizing reality in a way that is meaningful to them. This theory of cognitive constructivism provides a perspective for viewing the child as an engineer of personal understanding. (p. 8)

According to Mayer and Fortner (1995), meaningful learning is about conceptual change. In order to help facilitate student’s construction of knowledge, ESE proposed one model for teaching that allows students to have the types of experiences called the learning cycle. The learning cycle, developed by Karplus (1977), supports constructivist ideas. Students can construct their own understanding and meaning about concepts with real materials, and they are provided more than one experience with the concept. Finally, teachers can provide opportunities for students to apply the concept to a new situation or further explore the concept.

**Authentic School Activities**

One component of a successful constructivist lesson/unit is the introduction of a real-life problem (Klein & Merritt, 1994). From a constructivist perspective, teachers should provide authentic (real world) classroom activities in order for students to apply in-school experiences effectively into their out-of-school life. Teachers should know that students have their own points of view and they can make decisions about what is valuable to them. In addition, Brooks and Brooks (1999) explain appropriate content of a lesson using the constructivist approach and describe that “the constructivist approach to teaching presents these real-world possibilities to
students, then helps the students generate the abstractions that bind these phenomena together" (p. 104). Berlin and Woolard (1988) also suggest that middle school learners should be involved in study of high-interest material related to their daily lives, and benefit from investigations involving nontraditional school environments.

As Jax (1995) describes, one important aspect of ESE is an emphasis on providing students the opportunities to explore some of the major issues in science involving the Earth. For example, five sets of curriculum activities about integrated sciences and human interactions, the Earth Systems-Education Activities for Great Lakes Schools (ES-EAGLS), explore these issues in a Great Lakes context for students in secondary schools located near the Great Lakes (Earth Systems Education, 2000). The ES-EAGLS is based on interdisciplinary investigations and global concepts approached on a regional basis. For instance, “Climate & Water Movement”, one of ES-EAGLS, includes interesting problems and themes suggested by everyday experiences such as basic principles of lake effect, climate/water relationships, storm surges/lake levels relationships, seasons on the Great Lakes, and climate/water relationship to the Great Lakes region (Fortner & Meyer, 1996). Furthermore, the primary themes and contents of other ESE activity books are highly related to real world experiences (Fortner & Meyer, 1996; Fortner & Miller, 1997; Fortner, Miller, & Sheaffer, 1995; Fortner, Meyer, & Sheaffer, 1996; Fortner, Sheaffer, & Miller, 1997a, 1997b; Mayer, Fortner, & Murphy, 1993).
Learning Process (Assessing Prior Knowledge)

Constructivists make different assumptions concerning learning processes. A constructivist view of teaching and learning has proven to be a powerful model to describe how conceptual change in learners may be promoted. One important principle of this approach is that learners can only make sense of new situations in terms of their existing understanding (Naylor & Keogh, 1999). Naylor and Keogh also emphasize that the learning process should be based on linking students’ pre-existing experience and knowledge.

Bednar and Charles (1999) describe that “constructivists believe that the way we learn is by interpreting our experiences based on our prior knowledge, constructing meaning and later revising our understanding by reasoning through new experience” (p. 2). Therefore, constructivists strongly suggest that teachers start to examine students’ pre-existing knowledge. The teacher’s first step is “to discover where the child is up to now and then seek to challenge those ideas which the child holds which run counter to accepted scientific views” (Cross, 1998, p.87). In addition, Brooks and Brooks (1999) argue that the teachers should seek “the students’ points of view in order to understand students’ present conceptions for use in subsequent lessons” (p. 17).

IESS teaching strategies emphasize assessing students’ prior knowledge. ESE (Mayer & Fortner, 1995) provides the following useful methods for determining prior knowledge and possible misconceptions:

1) observation and conversation with students
2) recording anecdotal notes

3) developing a checklist to record knowledge and skills

4) using KWL Model (Ogle, 1986). In this model, students are first asked to list what they know (K) about a particular topic before they read about it. Then, students identify what they want to know (W) about the topic. After reading, they analyze what they have learned (L).

5) concept mapping.

ESE's ideas of the nature of learning are very compatible with the current ideas proposed by constructivists.

**Learning Process (Assessing Student Learning)**

Assessment of student learning in a constructivist classroom should include attention to the measurement of learning that has value beyond the classroom and that is meaningful to students (Brown, 1998). Authentic measures of learning require students to demonstrate their process during the classroom activity or lesson. Brooks and Brooks (1999) describe, “Assessment of student learning is interwoven with teaching and occurs through teacher observations of students at work and through student exhibitions and portfolios” (p. 17).

Jonassen (1992) also states

Most constructivistic environments…assume that instruction should be anchored in some meaningful, real-world context. Therefore, it is equally important that evaluation occur in contexts that are just as rich and complex as those used during instruction. (p.141)
ESE uses several different types of assessment strategies based on constructivism. First, concept mapping is a useful technique for measuring prior knowledge, then students' conceptual change and understanding. Second, as Brooks and Brooks (1999) suggest, teachers in ESE classroom should encourage the use of portfolios as “work in progress” in order to demonstrate how students have improved their work during the process of developing it. This portfolio assessment can provide students, teachers, and parents with continuous, multidimensional evidence and a picture of students' growth and abilities. Third, ESE suggests that knowledge and skills can be measured with performance assessments, as when students are given a set of directions, some manipulatives, and some questions to answer. A performance assessment, for example, might measure students' abilities to read directions, measure accurately, read a chart, and make a conclusion. Another important type of assessment in ESE is using rubrics to evaluate individual student reports, presentations, projects, and works. Curriculum materials developed for ESE include rubric models (Mayer & Fortner, 1995).

**Teachers' Role**

From a constructivist perspective, a teacher in a classroom should be a facilitator not a knowledge provider. Driver (1995) suggests,

The teacher needs to provide the necessary experiences to enable students' science understandings to relate to events and phenomena. However, experience by itself is not enough. It is the sense that students make of it that
matters. If students’ understanding are to be changed toward those of accepted science, then intervention and negotiation with an authority, usually the teacher, is essential. (p. 399)

Likewise, Bentley and Watts (1994) state,

The teacher should start where the learner is. They enable individual learning through focused experience and then use children’s range of experiences to further understandings … Teachers are facilitators. Teachers encourage children to explore ideas themselves rather than being directive themselves. (pp. 10-11)

The ESE perspective views the teacher as both a provider of experience and a presenter of information to facilitate growth in knowledge. In ESE instruction, the teachers are all concerned with helping students learn new knowledge and skills related to the Earth’s systems. ESE teachers go beyond simply changing the content of their science curricula. The teacher in ESE classes is seldom in front of the group delivering information. Instead, students are engaged in productive group activity, obtaining and sharing information about the problem or Earth process under consideration (Mayer & Fortner, 1995).

In summary, many ESE ideas about teaching and learning processes are based on constructivist ideas. Each component of ESE teaching and learning strategies includes student-centered instruction facilitated by the teacher, productive group interaction during the learning process, authentic classroom tasks, introduction of a real-world problem, social interaction and discourse as part of learning, the
teacher as facilitator and resource provider, and most importantly, the students as agents of the classroom environment and learning. I use these theoretical components when I observe the ESE classes.
CHAPTER 3

METHODOLOGY

Introduction

Chapter 3 provides a description of the research methodology and procedures used in this study, including the methodological perspective, the researcher, research design, pilot study, research site, participants, data collection methods, data analysis procedures, and strategies to ensure trustworthiness. The chapter opens with a description of the paradigm debates between the positivist paradigm and the naturalistic paradigm and the methodological perspective framing the mixed method design that guided the procedures of this study.

Methodological Perspective

Over the past three decades, paradigm debates have occurred in the social and behavioral sciences regarding the superiority of one or the other of the two major social paradigms or models: positivist paradigm vs. naturalistic paradigm (Cronbach, 1982; Greene, Caracelli, & Graham, 1989; Guba & Lincoln, 1994; Rossi, 1994; Tashakkori & Teddlie, 1998).

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According to Tashakkori and Teddlie (1998), an example of these paradigm debates between scholars such as Cronbach and Cook and Campbell during the 1970s and 1980s showed that the debates focused on "the relative importance of internal validity [emphasizing controlled settings, which were considered sacrosanct by the positivists] and external validity [emphasizing natural settings, which were preferred by the constructivists]" (p. 4). In the 1990s, there were several conceptual issues between the two paradigms, such as the "nature of reality" or the "possibility of causal linkages" (pp. 4-5).

Inquiry in the positivist paradigm involves the collection of numerical data in order to explain, predict, and control phenomena of interest, while inquiry in the naturalistic paradigm involves the collection of extensive narrative data in order to gain insights into phenomena of interest (Campbell & Stanley, 1971; Cook & Campbell, 1979; Creswell, 1994; Glesne, 1999; Guba & Lincoln, 1994; Lincoln & Guba, 1985; Yin, 1993). Because both paradigms have different philosophical beliefs and methodological characteristics, both positivist and naturalistic inquiries are valuable types of research that further our understanding of educational phenomena. The findings and results from both positivist and naturalistic research can help positivist inquirers as well as naturalistic inquirers to enhance their own theoretical background and knowledge.

The effectiveness of research methods is closely related to the nature of the research questions and purposes of the investigation. In other words, the best research method is the one that can answer the research questions most efficiently.
According to Lincoln and Guba (1985), if the purpose of a study is to investigate or understand what is happening in a particular setting, then a qualitative method (naturalistic inquiry) is the answer. Among qualitative research methods, a case study is “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 1994, p. 13). According to Shaw (1978), case studies “concentrate attention on the way particular groups of people confront specific problems, taking a holistic view of the situation” (p. 2). “By concentrating on a single phenomenon or entity (the case), the researcher aims to uncover the interaction of significant factors characteristic of the phenomenon. The case study focuses on holistic description and explanation” (Merriam, 1998, p. 29).

This study is primarily focusing on one middle school science teacher’s IESS teaching and learning experiences in a natural context. Therefore, a case study was deemed most suitable. This approach was supplemented by a quantitative method and analysis (i.e., survey) during the pilot study and after qualitative data collection. The “mixed methodology design” provided a broader and more complete picture of IESS curriculum and instruction and comprehensive understandings of ESE as a new integrated science approach (Creswell, 1994).

The Researcher

In a qualitative case study, a researcher is the primary instrument for gathering and analyzing data, therefore a qualitative report should include
information and background about the researcher (Lincoln & Guba, 1985; Merriam, 1998; Patton, 1990). I have a different educational background and research experiences from those of American researchers. Even though my research context was in America, I conducted this study with my own educational, social, and cultural points of view. Thus, in this section, I briefly explain my educational background and the integrated science education in Korea that shaped my educational perspective.

I have been a full-time doctoral student in a science education program since 1998. During this time, I had opportunities to observe two high schools, one middle school, and one elementary school as a part of my coursework; to conduct individual projects with several teachers; and to learn the history, philosophy, and educational systems associated with American science education. In addition, I have assisted a professor in teaching undergraduate courses as a mentor for several quarters. Throughout these experiences, I have learned many basic ideas about the American educational system and was becoming familiar with schools and students.

Before coming the U.S., I had primary and secondary education for 12 years in Korea: 6 years in elementary school, 3 years in middle school, and 3 years in high school based on a ladder-type, 6-3-3 schooling system. Korea has a centralized educational system controlled by the Ministry of Education (MOE) since 1948. Therefore, all school curriculum content, school systems, and time allocations are uniform with a few variations depending on the regional and local situations.
My major educational experiences include 4 years of undergraduate study, majoring in Earth Science Education, and 2 years of graduate study in Earth Science Education and Geology. I worked at the Department of Earth Science Education in the Korea National University of Education for 28 months as a full-time administrative and teaching associate.

Throughout the history of the revision of the Korean science curriculum, there have been national efforts to provide integrated science education for all students. However, the Korean national science curriculum for an integrated science course did not meet a nationally recognized need for goals that could improve the quality of science education for all students. While I was teaching undergraduate students who would be teaching integrated science and Earth science in a secondary school, I strongly believed that we needed a new approach to integrated science education. In addition, I had an opportunity to attend the second International Conference on Geoscience Education held in 1997 with “Learning About the Earth as a System” as a main theme. Since the conference, I realized that we needed to re-examine traditional Korean Earth science education and integrated science education for a new global era. I believed that ESE provided the organizing conceptual theme and focus for developing an integrated science curriculum for secondary education. ESE plays a central role in restructuring current traditional Earth science education and integrated science education for the new global era. Thus, I became interested in the ESE model and framework when I was in the Masters’ program in Korea.
Based on my educational experiences and interests in Korea and the U.S, I conducted this case study. The school where this study was conducted has been identified as an exemplary case in implementing ESE to integrate their science curriculum. The teacher and students provided me the opportunity to investigate ESE at the middle school level, and to explore the nature and characteristics of the IESS curriculum and instruction.

**Research Design**

The research design in the study adopted a “sequential mixed method design” defined by Tashakkori and Teddlie (1998). (See Figure 3.1.) They explain that “In sequential mixed method designs, the researcher conducts a qualitative phase of a study and then a separate quantitative phase, or vice versa” (p. 46). The design of this study has two similarities with their design. First, qualitative and quantitative processes are somewhat sequential in this design. After I completed the preliminary findings from qualitative observations and interviews, and documents analysis, I used those findings to develop the exploratory survey instrument. In other words, I conducted a qualitative phase of the research and then a quantitative phase during my pilot study. However, during the major phase of the study, the qualitative and quantitative data was collected at the same time and analyzed in both qualitative and statistical manners.
Figure 3.1: Brief overview of mixed method design.
Second, two methodological processes are somewhat separate and distinct because the survey research method was mainly trying to answer my research questions 5 and 6. Therefore, the survey results did not necessarily provide more evidence to support all qualitative findings in the design.

The qualitative method involved conducting interviews with the IESS teacher and students, observing science classroom activities and field trips, and documents analysis. The survey was also employed to 1) elaborate on students’ views on characteristics of IESS curriculum and instruction, evaluation methods, instructional materials, field trips, and mini-projects; 2) explore students’ self-reported knowledge, self-perceived significance of 13 selected Earth systems and environmental topics, and their primary information source on those topics; and 3) investigate how self-reported knowledge and perceived significance of Earth systems concepts and topics related to IESS differ with a comparison group.

Pilot Study

In the Autumn quarter of 2000, a pilot study was performed using guidelines and instruction suggested by Dr. Rosanne W. Fortner. She developed and taught a new course, NR 814 Earth Systems Education, for introducing both science and education majors to the interdisciplinary aspects of ESE. According to Dr. Fortner’s recommendation, a local exemplary classroom was selected in a middle school, and entry was obtained through permission granted by the principal and teacher at the school.
Preliminary outcomes from one week of classroom observations, an interview with the teacher, and a short survey given to 37 students gave me some insight into ESE and helped to focus the orientation of the study. The outcomes of the pilot study were consistent with findings from the literature review. In addition, I was convinced that the use of both qualitative and quantitative methods could provide more descriptive and analytical accounts of IESS teaching and learning in one middle school classroom because methodological triangulation could support the findings from both methods.

Preliminary Findings from the Pilot Study

In the middle of October 2000, I visited an IESS class instructed by Mr. Fox of 20 eighth grade students (11 male and 9 female students) at Lincoln Middle School. The class was conducted from 8:43-9:25 a.m. (second period), daily, 10 weeks in a quarter. Based on observations, an interview with the teacher, and documents, I described findings in five areas: curriculum, syllabus, teaching style and strategies, instructional materials, and content.

Curriculum

The Integrated Earth Systems Science (IESS) curriculum was a grass-roots effort of Mr. Fox and other science teachers in the middle school. Both the seventh and eighth grade integrated science curriculum were based on the Framework of the Seven Earth Systems Understandings and Earth system approach. The focus of the
seventh grade science was to begin locally and extend regionally, so students learned about what was going on in their own backyards and then extended their learning to local and state environmental issues (e.g., the Great Lakes). In the eighth grade curriculum, the focus began with local watersheds then extended to a global perspective. Global environmental issues included El Niño, global warming, ozone hole, etc. The curriculum was also designed for students to use aspects of biology, geology, and physical sciences to study their environment and their place in it, and to explore how the Earth systems have changed over time (Personal Communication, 10/17/00).

**Syllabus**

After I reviewed and analyzed the teacher’s syllabus of Earth Systems Science for eighth grade, my first finding was that all objectives in the units of syllabus fit well into the major features and themes of Earth Systems Education (see Table 3.1). For instance, one distinct characteristic in ESE is a locally relevant curriculum that meets the broad needs of students. In the syllabus, most science content within ESE was highly related to local science topics and environmental issues. In ESE, students were allowed to connect and apply their learning to their environment and local living place. According to the syllabus, each unit focused on Earth Systems Science and included local environmental issues and science topics (e.g., the biodiversity of our local community, Ohio wetlands, the quality of drinking water for Franklin County, OH).
Unit – Watersheds
Natural and human constructed water drainage systems are affected by human activity.
• Define and describe the urban watershed.
• Explain how humans are individually and collectively a part of the urban watershed.
• Describe the sources of drinking water for Franklin County, OH.
• Describe how the urban environment is a contributor to the quality of surface waters.
• Use topographic maps to explain why Ohio streams flow the way they do.
• Define drainage divides and tell where the major drainage divide in Ohio exists.
• Explain how human intervention in watersheds affects flooding.
• *Describe some of the sources of water pollution in the local community and the rest of Franklin County.
• *Describe the effects that water pollution has on an ecosystem.
• *Perform tests and other measurements to determine the physical characteristics of streams, including the chemistry of the water, its temperature, velocity, depth and discharge.
• *Describe how the water quality of portions of streams can be monitored by chemical and biological means.
• Describe how we can reduce the amount of water pollution coming from residential areas.
* Note: These objectives are dealt with in classroom activities and are strongly reinforced by a one day field trip to Battelle-Darby Metro Park.

Unit – Wetlands
Wetlands are parts of watersheds that have high amounts of biodiversity and are sensitive to human impact.
• + Explain the functions that wetlands serve in the environment.
• + Observe and describe some Ohio wetlands.
• + Describe the value (to humans) of wetlands.
• + Describe the biodiversity of wetlands.
• + Measure the physical parameters of an Ohio wetland.
• + Discuss the relationships among the biotic and abiotic factors in an Ohio wetland.
(continues)
Table 3.1 (continued)

- Explain why the number and total area of wetlands has been decreasing in the last 150 years.
- Explain how human activity can have an impact on the quality of water in a wetland.
- Compare the biotic and abiotic factors of Tar Hollow State Park, Pickerington Ponds Metro Park and Battelle-Darby Metro Park and explain the differences.

+ Note: These objectives are dealt with in classroom activities and are strongly reinforced by a one day field trip to Pickerington Ponds Metro Park.

Unit – Biodiversity
- Describe how biodiversity in an ecosystem can be determined.
- Explain the genetic basis of biodiversity.
- Describe the biodiversity of our local community.
- Compare the biodiversity of our local community with other areas, including wetlands.
- Explain why biodiversity is important to humans.
- Explain how biodiversity has changed over time.
- Describe how humans have affected biodiversity.
- Explain how deforestation affects biodiversity (Ohio and globally)

Unit – Change Through Time
Daily changes in Earth’s atmosphere is what we call weather. Longer term changes are associated with climate. The climate of Earth has changed over different time scales in the past. Climate may be changing at the present time and in the near future.

- Explain how and why weather affects us each day.
- Explain how climate has changed over time (thousands to millions of years)
- Use proxy data (tree rings, coral banding, ice cores, glacial deposits) to describe past climate.
- Describe what happens to biodiversity when climate changes.
- Describe how humans have affected climate change (global warming).
- Explain how climate change may have affected human populations in the past (Anasazi).
- Explain how deforestation affects climate.
- Describe how climates on Venus and Mars can be used to help explain global climate change on Earth.
- Explain how such geological events as volcanic eruptions can affect climate.
- Describe how human activity causes other changes in Earth’s atmosphere, including ozone depletion and acid rain.

(continues)
Table 3.1 (continued)

Earth’s lithosphere and life have evolved over long periods of time. Plate tectonics processes have had some influence on organic evolution.

- Use fossil evidence to explain how life on Earth has changed over the last 625 million years.
- Explain how geographic isolation can affect populations of organisms.
- Explain why volcanoes and earthquakes are located where they are.
- Describe four different lithospheric plate boundaries, the features associated with each and what happens to the lithosphere there.
- Explain what might cause extinctions to occur.
- Explain why some species survive environmental change better than others.
- Explain how lithospheric and organic evolution are related.
- Describe what may have caused the extinctions at the end of the Cretaceous.

Unit – Ohio’s Natural Resources
Ohio is quite fortunate to have a wide variety of natural resources. The use of these resources can lead to some environmental problems.

- Use maps to locate resources found in Ohio.
- Explain how these resources are obtained.
- Describe the mineral and fossil fuel resources of Ohio.
- Explain how these resources formed.
- Explain how the use of these resources affects the environment.
- Describe energy resources (alternative energy sources) that are available to replace fossil fuels.
- Discuss the relative merits of alternative energy sources.

Teaching Styles and Strategies

The class usually began with checking the assignment and announcements. I thought the teacher’s style was informal and relaxed, but in control of the class.

During the observations, he primarily used a combination of standard lecture and
group work. He promoted a very interactive atmosphere. He wanted the students not to just sit and listen to a lecture. Students were active participants in generating new ideas and questions.

**Instructional Materials**

I found that there was no official textbook in this science class. During my pilot study, I felt that students seemed to enjoy science learning without textbooks. In my short written survey, I asked students to explain the major reasons why they enjoyed or disliked the current science class, if they liked or disliked science classes. Thirty-three out of 37 students responded that they liked to learn science. In general, these students expressed positive attitudes about no textbook (all student names in this study were replaced to protect the identity of those involved in the study), as shown by their responses:

*Jeffrey:* I enjoy having the teacher I have because he teaches things in fun easy to learn things. I have always enjoyed science because of what it deals with. Not having a textbook makes things easier to expand upon. Science is really interesting.

*Debra:* I think the reason I like science is very interesting and we learn it in more of a hands on way instead of just reading it out of books, like we do in other classes.

*Patricia:* Mr. Fox is a good teacher and our class is very flexible because we don't have textbooks, I feel we have more fun and learn more with this system.

*James:* I like learning science without a textbook because it helps you concentrate better. When you are learning from a textbook
it's really hard to remember what you learned because it's so boring. But learning without a textbook we got more involved and have fun which makes us remember and learn.

Robert: I like not using a textbook because it makes the class more interesting and fun. I also like doing experiments in class.

The other 4 students responded that they did not like to learn science, as shown by their responses:

Sharon: Difficult to understand, don't feel that I need to know what I am being taught.

Howard: It's doesn't usually click with me like other things the first time I hear it. I wish it were more fun, more trips. I'm glad I will be in basic science next year because it will not be too hard. It's just too complex to understand.

Richard: Science doesn't interest me.

Derrick: I don't really have a main reason why I don't like it.

Students were given handouts which contained projects for them to work on, either individually or in groups. One packet they were given involved microorganisms and sampling techniques. Another activity taught the students about biodiversity. The students also worked on a packet about biodiversity. This activity was tied to a previous field trip to Pickerington Ponds. All handouts and activities were included in each student’s notebook. Moreover, the classroom seemed quite well equipped. During my observations, a video camera, overhead projector, aquarium, and maps were used.
Content

The content was indeed interdisciplinary. This was evident in the student presentations, which were graded on format and content. Students were given projects, which included mathematics, randomness, language arts, Ohio’s natural history, and questions on how water affects plants and animals. The teacher stressed that the data used was real life data. On the first day of the observation, a student question turned into a discussion on the reasons why some estuaries had muddy bottoms and others had rocky bottoms. This discussion involved topics such as biotic organisms and water movement. Student use of notes and documentations of sources were also strongly encouraged.

Research Site

After reviewing various sampling techniques used in both qualitative and quantitative research, purposive sampling seemed to best fit this study. The purposive sampling used in qualitative case study is “based on the assumption that one wants to discover, understand, and gain insight; therefore, one needs to select a sample from which one can learn the most” (Merriam, 1988, p. 48). As Patton (1990) describes, “the logic and power of purposeful sampling lies in selecting information-rich cases for study in-depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research” (p. 169). While I observed what was occurring in Mr. Fox’s classes, his IESS-based
curriculum and instruction and his students' learning activities during the pilot study suggested that Mr. Fox and his science classroom in the Lincoln Middle School was an information-rich site for my case study.

The primary research locations were Mr. Fox's science classroom in the middle school and field trip locations. The middle school selected for this study is located in the eastern area of a large city in Ohio in an upper-middle class community. In 1997, this Lincoln City School District was recognized as one of the highest performing school districts in Ohio. The performance on proficiency tests by students enrolled in this school district was higher than the state average. Students attending the Lincoln High School in the same school district are predominantly college bound - more than 90% of the high school students attend colleges and universities.

The classroom setting in which all instruction takes place is modern and well equipped. In Mr. Fox's classroom, two computers with Internet access and printers are available for student use (see Figure 3.2). Class sizes were around 20 or more students depending on periods. There was a chalk board in the front of the classroom. There were seven large tables in the classroom. Usually, 2-3 students sit together at the same table. This classroom included good lab facilities (e.g., sink, shelves for lab equipment). Therefore, students could do any lab activities in Mr. Fox's classroom. I found many useful scientific posters on the wall, such as a Glacial Map of Ohio, Seven Understandings of Earth Systems Education, Principle Streams...
and their Drainage Areas, and a world map. One small stock room was connected with the classroom for storage of resources, teaching materials, and teacher references and books.

Figure 3.2: Images of classroom view: 1. Two computers with Internet connection, printer, and maps; 2. Classroom view; 3. Maps, posters, aquarium, TV, and VCR; 4. Room-size concept map.

This research has been conducted since January 2001 at the middle school. Permission to access the teacher and students was obtained from Mr. W., Principal, prior to this study. After I received formal approval to do my study from the Human Subjects Review Board at The Ohio State University (see Appendix A) on February 73.
written consents were also obtained from all students agreeing to participate in this study and their parent or guardian (see Appendices B, C, & D).

Participants

Teacher

This study primarily focuses on one eighth grader teacher, Mr. Fox, who developed the IESS curriculum and utilizes ESE-based curriculum and instruction. He is not only a well-known person to educators in ESE, but also an enthusiastic teacher. He has more than 20 years of teaching experience in middle school. After completing his master’s degree in science education, he finished his Ph.D. in the same area in 1995. In his doctoral dissertation, he conducted a case study that examined the nature of, and the processes involved in, the initiation and implementation of an innovative two-year science curriculum [Earth systems curriculum] for ninth and tenth grades, in a suburban school district. The new ESE-based science curriculum at the high school in that same district replaced more traditional Earth science and biology courses at the 9th- and 10th-grade levels. His study focused on the teachers involved in the change process and the influence that other stakeholders (e.g., teachers, administrators, parents), as well as external factors (e.g., local university educators, external funding sources, etc.), had on the process.
One finding from his study indicated that

Group learning, alternative assessment and the use of new technology have been an important part of the instructional changes that occurred as a part of the new curriculum. The teachers were the primary instigators of change and were the ones who, with the help of facilitators both inside and outside the school district, developed the Earth systems curriculum at Central High. Instead of curriculum being imposed hierarchically, it was a grass-roots process. (Jax, 1995, p. 215)

Mr. Fox's major interests focus on ESE as an innovative integrated science curriculum, and the Earth system approach to curriculum integration. He is very familiar with the seven understandings of the ESE framework and principles of ESE-based teaching and learning. He was one of two project members in the "Program for Leadership in Earth Systems Education" (PLESE) and "Biological and Earth Systems Science" (BESS) projects, as well as a leader for the central Ohio Middle School Earth Systems Education team.

He has implemented an IESS curriculum for 7th and 8th grades in his middle school since 1992 and has incorporated ideas and principles of ESE into his instruction. He and the other five science teachers at the middle school have developed a new science curriculum that focuses on an Earth system approach that has been developed over the past years through several projects at The Ohio State University.
Mr. Fox's Students and Comparison Students

In addition to Mr. Fox as an information-rich case for the study, 41 eighth graders in the second and fourth periods at Lincoln Middle School were initially invited to participate in this study. Even though Mr. Fox was teaching five periods a day, I was only able to observe two morning classes due to my schedule. The population of the middle school was multi-cultural, consisting of Caucasian, African American, Asian, and Hispanic students (Ohio Department of Education, 2000). However, all Mr. Fox's students in both second and fourth periods were Caucasians. They were born in either 1986 or 1987. The second period (8:43-9:25 a.m.) included 11 male and 9 female students, whereas the fourth period (10:13-10:55 a.m.) consisted of 10 male and 11 female students. Since Mr. Fox was teaching the same content repeatedly for five periods, I could not find any instructional differences between the second and fourth period. It appeared to me that students in the fourth period were a little more actively engaged that the ones in the second period. I asked the teacher if there were any identified differences between the two classes. He said "not really" except that students seem to be more awake late in the morning.

After I obtained permission from the principal and parents or guardians, I observed Mr. Fox's instruction and interacted with students during his two morning classes. When students were asked to participate in individual interviews, nine students volunteered, including four boys and five girls. Therefore, I interviewed only nine students during this study. Their individual characteristics are described briefly in Chapter 5.
In order to provide a broader perspective of ESE, a survey was administered to all Mr. Fox's students who enrolled in his second, fourth, fifth, sixth, and seventh periods. There were 51 male students (50%) and 51 female students (50%). Fifty-five students were born in 1987 and 47 students were born in 1986. In addition, Mr. Fox's students' self-reported knowledge and self-perceived significance levels on Earth systems concepts and environment topics were compared with a comparison group of students from another middle school. The comparison school was conveniently chosen from one of 22 similar districts identified by the Ohio Department of Education (Ohio Department of Education, 2001). The Ohio Department of Education established a consistent and objective method of determining similar districts. They used the following five dimensions to determine a district's comparison grouping: 1) district size; 2) poverty level; 3) socioeconomic status (e.g., family income, education levels and professions); 4) factors related to urban or rural location; and 5) district property tax wealth.

The comparison school is located in an upper-middle class community in the upper northeast area of a large city in Ohio. I surveyed 94 eighth graders who had the same science teacher. Of all 94 comparison students, 51 % (48) were male and 49 % (46) were female, 56 % (53) were born in 1987 and 44 % (41) reported that they were born in 1986. The comparison students had never been exposed to Earth Systems Education. They served as the comparison group to only compare
self-reported knowledge and self-perceived significance levels, and their primary information source on Earth systems and environmental topics. Therefore, only items in Part I of the survey instrument were distributed to the comparison group.

**Collecting Evidence**

For purposes of triangulation, evidence was collected from several major data sources: classroom observations, semi-structured interviews with Mr. Fox and his students, documents, self-reported data from the teacher, and quantitative data through the survey. Videotape recordings were used while observing instruction and interviewing because videotaping was very helpful for ensuring the descriptive validity of my observations, and stimulating recall and reflection as a component of some of the interviews with participants. Five specific data sources are discussed in this section.

**Background Information Form**

Mr. Fox was asked to complete the Background Information Form (see Appendix E) before any interview and observations. The information that was requested includes: personal information, education, teaching certification, current teaching position, past teaching experience, and membership in professional organizations. This information is used to provide a better understanding about the teacher as well as describing background data in the final write-up of this study.
Interviews

I interviewed Mr. Fox and his students in order to get more of a sense of how they perceive the IESS curriculum and instruction. This was a meaningful qualitative research strategy because the interviewing provides an opportunity for the researcher to access the participants’ perspective, and to look inside their minds, feelings, and thoughts (Glesne, 1999; Patton, 1990). Thus, qualitative interviewing requires “intense listening, a respect for and curiosity about what people say, and a systematic effort to really hear and understand what people tell you” (Rubin & Rubin, 1995, p. 17). The advantage of interview over other qualitative data collection methods is affirmed by Patton (1990):

The fact of the matter is that we cannot observe everything. We cannot observe feelings, thoughts, and intentions. We cannot observe behaviors that took place at some previous point in time. We cannot observe situations that preclude the presence of an observer. We cannot observe how people have organized the world and the meanings they attach to what goes on in the world. We have to ask people questions about those things. (p. 278)

Two types of interview were used in the study. One type was a semi-structured, open-ended interview with Mr. Fox and his students. Protocol #1 (see Appendix F) was administered to Mr. Fox. The interview was used to investigate the teacher’s views about the ESE framework, IESS teaching and learning, issues related to implementing IESS curriculum and instruction, and field trips as well as opinions on the difficulties, barriers, and advantages of IESS. To obtain more rich, deep, and specific answers, Mr. Fox’s interview responses were followed up in a written
question format (see Appendix G). Interview Protocol #2 (see Appendix H) was used to examine students' views on characteristics of IESS curriculum and instruction, evaluation methods, instructional materials, and field trips.

The second type was an "informal interview" with Mr. Fox and the students. If I found something interesting happening and unfamiliar events during the class observation, I asked the teacher or students during breaks or after the class. As Patton (1990) describes,

The strength of the informal conversational approach is that it allows the interviewer/evaluator to be highly responsive to individual differences and situational changes. Questions can be individualized to establish in-depth communication with the person being interviewed and to make use of the immediate surroundings and situation to increase the concreteness and immediacy of the interview questions and responses. (p. 282)

Interviews were recorded and selectively transcribed for analysis purposes to confirm or disconfirm patterns in teacher responses to the interview and written questions and patterns in student responses to the interview questions.

**Observations**

Classroom observations were conducted throughout the study in order to collect data related to Mr. Fox's instructional activities, actions, classroom organizational processes, and students' responses and activities. According to Patton (1990),

The purpose of observational data is to describe the setting that was observed, the activities that took place in that setting, the people who
participated in those activities, and the meanings of what was observed from the perspective of those observed. (p. 202)

In addition, the observation is likely to take different forms at different stages of the inquiry. Early on, the observation may be very unstructured, a stage of defocusing or immersion in order to permit the observer to expand his or her tacit knowledge and to develop some sense of what is seminal or salient. Later, the observations may become more focused as insights and information grow. (Lincoln & Guba, 1985, p. 275)

In this study, participant observation was chosen because I wanted to be directly involved in the classroom as an actual participant. Before my pilot study, I was concerned that the videotape recorder would influence the students to act unnatural in their classroom environment. However, I realized that the students seemed to feel comfortable about the researcher being there and observing them as a participant observer. I already experienced that “as our awareness of presence increased, confidence in our judgment grew and research dispositions took on more depth” (Roberts & McGinty, 1995, p. 120-121).

The use of a videotape recorder was very helpful in gathering more accurate information. Videotape recordings were selectively analyzed to present sufficient evidence about instructional activities, repeated teaching patterns and sequences, and any characteristics presented by the teacher. In addition to videotaping, I used my descriptive and reflective field notes right after the observations. As Fraenkel and Wallen (1996) describe, the reflective field notes “describe the setting, the people and what they do according to what the researcher observes” (p. 460). Through the
guidance and suggestions of Dr. Patti Lather, who taught “Practicum in Qualitative Research Methods” at The Ohio State University, I developed my own field note format (see Appendix I). This field note format has a left column for writing the descriptive notes, and a right column for writing my methodological and/or theoretical reflection. I realized that this note format was very useful in writing and reflecting what I observed, thought, felt, and so on.

After I collected data from observations, the field notes included a description of the physical setting, my comments and feelings, reactions to the experience, reflections, accounts of particular events, reconstructions of conversations, and additional portraits of the participants. The descriptions and reflections became another source of data.

**Documents Analysis**

I examined documents, such as the curriculum framework, instructional resources and materials, and teacher’s handouts. These documents were “objective” sources compared to other forms because my presence does not alter what is being studied (Merriam, 1998). The documentary data were particularly good sources for this case study because they gave me ideas about important questions to pursue through more direct observations and interviewing. In addition, I looked at students’ grades, test scores, and attendance records to help me gather general information about the students. As Glesne (1999) suggests, documents that provide demographic, historical, and some specific student information are important to a case study.
During the pilot study, I recognized that students’ notebooks were a very important source for my study because the notebooks were composed of all materials, handouts, group projects, individual projects, exams, quizzes and other worksheets used throughout the science classes. Therefore, I examined students’ notebooks carefully because their notebooks were very helpful as they provided evidence of science content, evaluation methods, students’ projects, and the sequence of topics presented in the science classes that were unavailable from other data sources. These documents corroborated my observations and interviews, and thus made my findings more trustworthy.

Survey

As described in the Participant Section, the survey was administered to all of Mr. Fox’s students in the eighth grade. They consisted of 51 male and 51 female students. In addition, I surveyed 94 students, drawn from one middle school located in a metropolitan area of a large city in Ohio. The survey instrument was developed through modification of two questionnaires from Jax (1995) and J. Lee (2000). (See Appendix J.) The survey was designed to explore and identify any quantitative evidence related to students’ views about the IESS curriculum and instruction and components of ESE, students’ self-reported knowledge and self-perceived significance levels of Earth systems concepts and environmental topics, and their
primary information sources on those topics. For each item, there was a Likert-type rating scale of 1-6 (e.g., for knowledge section, 1 = not at all knowledgeable, 6 = very knowledgeable).

The survey instrument was divided into two parts. In the first and second sections of Part I, the instrument consisted of items to assess the degree of students' self-reported knowledge and self-perceived significance levels associated with 13 selected Earth systems and environmental topics, and to explore their primary information source on those 13 topics. As described in Chapter 2, ESE focuses on the interdisciplinary aspects within science disciplines and environment. One of the important features of ESE for school science curriculum is an emphasis on the use of Earth and Earth's subsystems as the context for the content to be covered (Mayer et al., 1992). Major contents in ESE are highly related to environmental issues and topics and Earth systems concepts. Thus, 13 classical, global and local environmental topics and issues were selected from several previous studies (Lee J., 2000; Lee & Fortner, 2000; Riechard & McGarrity, 1994; Riechard & Peterson, 1998), and from one popular environmental science textbook: *The Blue Planet: An Introduction to Earth System Science* by Skinner and Porter (1995). The 13 selected topics included acid rain, air pollution, deforestation, water pollution, global warming, introduced species, loss of biodiversity, oil spills, ozone hole, pesticides in agriculture, soil erosion, trash disposal, and El Niño.

The last section of Part I in the survey instrument was designed to assess the degree of students' self-reported knowledge and self-perceived significance levels
associated with 23 selected Earth systems concepts and themes. Seventeen out of 23 Earth systems concepts and themes were selected on the basis of the Framework of the Seven Earth Systems Understandings (Mayer, 1991b) and a series of the Earth Systems-Education Activities for Great Lakes Schools (ES-EAGLS; Fortner & Meyer, 1996; Fortner, Meyer, & Sheaffer, 1996; Fortner & Miller, 1997; Fortner, Miller, & Sheaffer, 1995; Fortner, Sheaffer, & Miller, 1997a, 1997b). The ES-EAGLS includes interesting topics and themes identified in each understanding of the framework of ESE. For instance, Part I-3 of the instrument includes four Earth systems concepts and topics related to the Earth Systems Understanding #5 (ESU#5) in the ESE Framework: Earth history, evolution, fossil evidence, and cycles in nature (e.g., water cycle, rock cycle, carbon cycle, etc.). As presented in Table 2.3, ESU#5 focuses on the great age of the Earth and the constant evolution of subsystems through time. The four concepts and topics were identified on the following basis of four specific descriptions:

**Understanding #5**: Planet Earth is more than 4 billion years old and its subsystems are continually evolving. *Earth history*

- **Earth’s cycles and natural processes** take place over time intervals ranging from fractions of seconds to billions of years.
- Materials making up planet Earth have been **recycled** many times.
- **Fossils** provide the evidence that life has evolved interactively with Earth through geologic time.
- **Evolution** is a theory that explains how life has changed through time.

In addition, five local topics and concepts were selected from the following three units in the Mr. Fox’s syllabus: Watersheds Unit (Item 20), Biodiversity Unit (Item 17), and Ohio’s Natural Resources Unit (Items 21, 22, and 23). 85

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In Part II, 37 items were used to measure students' views about the characteristics of the IESS curriculum and instruction, evaluation, instructional materials, field trips, mini-projects, and major concepts and themes within the ESE framework. Thirty-three out of 37 items were selected from the survey instrument which was developed to measure students' perceptions of the new Earth systems curriculum and its goals by Jax (1995). The other 4 items were developed by the researcher. According to the sub-categories of the items used by Jax and the major meaning and concepts of the Seven Earth Systems Understandings (Mayer, 1991b), 37 items were grouped and then used to describe students' views on each characteristic of the IESS curriculum and instruction and perceptions of the ESE Framework. The outline below matches the ESE framework with question numbers on Part I-3 and Part II of the survey instrument.

* The Framework of the Seven Earth Systems Understandings (ESUs)
  ESU#1: 1 (Part I-3) + 1, 2, 3, 14 (Part II)
  ESU#2: 2, 12 (Part I-3) + 10, 11, 15, 29 (Part II)
  ESU#3: 3 (Part I-3) + 4, 9, 16, 17, 32 (Part II)
  ESU#4: 4, 6, 7, 8, 13 (Part I-3) + 5, 7, 28, 30, 31 (Part II)
  ESU#5: 5, 9, 10, 14 (Part I-3)
  ESU#6: 11, 15, 16, 18 (Part I-3)
  ESU#7: 19 (Part I-3) + 8, 20, 21 (Part II)
  Local Topics: 17, 20, 21, 22, 23 (Part I-3)

  * Views (or Attitude) toward
  field trip: 26, 27 (Part II)
collaborative learning (teacher's strategy): 18, 19 (Part II)
teacher's style of teaching: 34 (Part II)
science content or topics: 6, 12, 22, 23 (Part II)
textbook: 13, 36 (Part II)
concept mapping: 25, 33 (Part II)
assessment methods: 37 (Part II)
science mini-projects and labs: 24, 35 (Part II)

In the last section of Part II, I asked for several types of demographic information, such as gender, favorite subject, year of birth, and overall grade.

In order to establish content validity, the following approaches were applied related to this survey. The instrument was reviewed and assessed by my co-advisors, one professor, and four doctoral students who are studying science education. In addition, one middle school teacher and Mr. Fox reviewed and evaluated the survey both during and after the development of the instrument. For face validity of the instrument, these teachers provided very useful suggestions and comments. All advice and comments were reflected in the content and form of the instrument. Further, a pilot test was administered to 37 students. During the test, I found that most students responded easily to most concepts and issues. However, several students asked questions about the meaning of several items and some environmental issues (e.g., loss of diversity and introduced species). After the test, several items were slightly revised through discussions with the teacher and advisors on the basis
of student questions. For example: Item 12 in Part II of the survey instrument was revised:

- **Before revision:** I would prefer to learn about science from a global perspective rather than from examples from around home.

- **After revision:** I would prefer to learn about science from a global perspective rather than from local examples.

The internal inconsistency of the final instrument was calculated using Cronbach's (1984) Coefficient Alpha after the items were modified. The results are an alpha coefficient of .88 for the self-reported knowledge section and a .88 for the self-perceived significance section related to the 13 Earth systems and environmental topics; a .94 for the self-reported knowledge section and a .90 for the self-perceived significance section related to the 23 Earth systems concepts; and a .93 for 37 statements in Part II of the survey (see Table 3.2).

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<tr>
<th>Survey</th>
<th>Cronbach Alpha Coefficients</th>
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<tr>
<td>Part I Self-Reported Knowledge Section (13 Earth systems and environmental topics)</td>
<td>.88</td>
</tr>
<tr>
<td>Self-Perceived Significance Section (13 Earth systems and environmental topics)</td>
<td>.88</td>
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<tr>
<td>Self-Reported Knowledge Section (23 Earth systems concepts)</td>
<td>.94</td>
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<tr>
<td>Self-Perceived Significance Section (23 Earth systems concepts)</td>
<td>.90</td>
</tr>
<tr>
<td>Part II 37 Statements</td>
<td>.93</td>
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Table 3.2: Cronbach’s alpha coefficients for internal inconsistency of each section in the survey.
In summary, this study extended from the autumn of 2000 through the spring of 2001. The pilot study was conducted October to December 2000. After I obtained the permission from the school, parents, and students, data were collected February to June 2001. I observed in Mr. Fox's classroom over a period of five months. The survey was used with all Mr. Fox's students near the end of school year (June 2001). Part I in the survey instrument was also completed by 94 eighth grade students in another school district for comparison purposes on May 2001. Table 3.3 summarizes the sources of data collection and time line of the study.

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<td>Feb. 2001 – June 2001</td>
<td>Data Collection</td>
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<tr>
<th>Data Sources</th>
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<th>Interviews</th>
<th>Observations</th>
<th>Document Analysis</th>
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T: Teacher; S: Students
C: Classroom; F: Field Trip

Table 3.3: Sources of data collection and time line.

Data Analysis Procedures

As Patton (1990) explained, "the purpose of qualitative inquiry is to produce findings. The process of data collection is not an end in itself. The culminating activities of qualitative inquiry are analysis, interpretation, and presentation of
findings" (p. 371). The end product of a case study is a rich “thick” description of the phenomenon under study (Merriam, 1998). Therefore, this case study provided the rich and literal description of evidence being investigated throughout data analysis.

Before analyzing the data collected in this study, videotapes and audiotapes from class observations and interviews were selectively transcribed. In order to manage the data, transcripts were organized and categorized according to date, data source type, participant’s name, and so on. The following major data sources were analyzed: interviews, documents, field notes, artifacts, observations, and data from the survey.

Data analysis was composed of three major tasks. The first task was to analyze Mr. Fox’s views concerning the ESE model, the teaching of IESS, and students’ views about IESS curriculum and instruction, IESS content, teaching materials, field trips, and mini-projects. This analysis focused on IESS curriculum and instruction in the classroom, and what ESE understandings or learning instructional strategies are presented or infused in the instruction by the teacher, and how the students perceive IESS and ESE.

Using inductive analysis (Patton, 1990) and constant comparative (Glaser & Strauss, 1967; Strauss, 1987) procedures, I reviewed classroom observations, interview transcripts, students’ notebooks, and field notes carefully and repeatedly, and then, I tried to look for key ideas, events, or activities in the data that became categories of focus. Evidence obtained from the study was categorized into topics and sub-topics and discussed in thick descriptions in order to allow the reader to
better understand IESS in a natural context (Fraenkel & Wallen, 1996). When I described and accounted for all the incidents I had in the data, I continually examined other data (e.g., survey) and searched for new incidents to discover connections and relationships for the interpretations (Bogdan & Biklen, 1992).

The second task of data analysis was to identify and document characteristics of IESS curriculum and instruction provided by the teacher. To answer the research question 3, I first read all transcriptions and written documents repeatedly and I tried to find rich evidence through “content analysis” of documents (focusing on students’ notebooks), interviews, and observations (Merriam, 1998).

With regard to identifying instructional strategies and patterns related to the teacher’s IESS instruction, I paid attention to certain words, phrases, patterns of behavior, and events that were repeated and stand out (Bogdan & Biklen, 1992). Transcripts were reread specifically to identify learning strategies. When I worked with my initial data, I used one function, “free node” in the Nudist 4.0 for MS Windows. This initial data reduction process is believed to be very helpful in narrowing the focus of an analysis in order to draw accurate conclusions (Miles & Huberman, 1994; Patton, 1990; Strauss & Corbin, 1990).

The third task of data analysis was a quantitative analysis. The computer program, Statistical Program for the Social Sciences (SPSS Ver.10.0 for MS Windows) was utilized for statistical analyses. Descriptive statistics were used to describe, analyze, and interpret the data that had been collected from the students in this survey. Multivariate analyses of variance (MANOVA) were conducted for the
following three sets derived from Part I of the survey: 1. self-reported knowledge and self-perceived significance levels of 13 selected Earth systems and environmental topics; 2. self-reported knowledge level of 23 Earth systems concepts and topics; and 3. self-perceived significance level of 23 Earth systems concepts and topics. If MANOVA was significant at a 95% confidence level, the follow-up univariate tests (ANOVAs) were conducted to determine the differences in the self-reported knowledge and self-perceived significance level mean scores of the 13 topics and 23 concepts and topics between Mr. Fox’s students and comparison students.

Regarding p value, a Bonferroni’s inequality principle was used to determine significance for all of the analyses (Klockars & Sax, 1986). To ensure an overall significance level of $\alpha$, each of the tests should reach significance at the $\alpha/c$ level where $c$ is the total number of comparisons made (Zolman, 1993). Thus, significance was determined at the 95% confidence level ($\alpha = 0.05/3 = .017$) for univariate ANOVAs. In addition, frequency and percentage distributions for each variable in Part II of the survey were used to describe students’ views on characteristics of IESS curriculum and instruction and understandings of the Framework of Earth Systems Education.

In summary, “parallel analysis” of qualitative and quantitative data is one of the most widely used mixed data analysis strategy in the social and behavioral sciences. This analysis provided “a richer understanding of the variables and their
relationships” (Tashakkori & Teddlie, 1998, p. 126). Each type of data analysis helps confirm and expand findings or evidence from one method of data analysis.

**Trustworthiness**

Schwandt (1997) states, “trustworthiness is one set of criteria that have been offered for judging the quality or goodness of inquiry” (p. 164). In order to judge the quality of research, positivist inquirers historically deal with internal validity, external validity, and reliability; however, these concepts do not transfer directly to naturalistic inquiry. Thus, naturalistic inquirers arrange for credibility, transferability, and dependability (Guba, 1981; Guba & Lincoln, 1989; Lincoln & Guba, 1985).

**Transferability**

Guba and Lincoln (1989) explain that

The positivist paradigm requires both sending and receiving contexts to be at least random samples from the same population. In constructivist paradigm, external validity is replaced by an empirical process for checking the degree of similarity between sending and receiving contexts... Generalization, in the conventional paradigm [positivist paradigm], is absolute, at least when conditions for randomization and sampling are met. But transferability is always relative and depends entirely on the degree to which salient conditions overlap or match. (p. 241)

Naturalistic inquirers do not intend to generalize their findings and results to the larger population. In fact, generalization might be impossible in qualitative research. First, the contexts and setting for naturalistic research are diverse. Second,
researchers usually conduct their research in a specific context and time. Therefore, the findings of an inquiry provide information related to a specific research setting, site, and time. Naturalistic inquirers believe that the findings can only become new information or working hypotheses for new inquiry and study. In place of generalization, they have an interest in transferring their outcome (working hypotheses) to another research that has a very similar context.

The major technique for establishing the degree of transferability is thick description (Guba & Lincoln, 1989). Lincoln and Guba (1985) also indicate that naturalistic inquirers are responsible for providing the widest possible range of information for inclusion in the thick description. Further, "the burden of proof for claimed generalizability is on the inquirer, while the burden of proof for claimed transferability is on the receiver" (p. 241).

During the process of reporting, I provided the thick description and rich evidence regarding my specific context and findings that could become good information for someone who is interested in making a transfer of my findings to his/her situation and research setting. Then, I interpreted the evidence the best I could.

*Credibility*

Credibility is parallel to internal validity in positivist terms. Schwandt (1997) stated, "Credibility addresses the issue of the inquirer providing assurances of the fit between the respondents’ views of their life ways and the inquirer’s reconstruction
and representation of the same” (p. 164). To establish credibility, naturalistic inquirers include prolonged engagement, persistent observation, triangulation, and member checks (Lincoln & Guba, 1985).

**Prolonged Engagement**

Prolonged engagement means that the researcher spends sufficient time “to build trust, learn the culture, and test for misinformation either from informants or from their own biases” (Tashakkori & Teddlie, 1998, p. 90). According to Lincoln and Guba (1985), prolonged engagement requires that the researcher should be involved with a site sufficiently long to detect and take account of distortions that might otherwise creep into the data. The period of prolonged engagement is intended to provide the researcher an opportunity to build trust. The longer the investigator is in the field, the more accepted he or she becomes, the more appreciative of local culture, the greater the likelihood that professional judgments will be influenced.

I spent more than a five-month period in the school. I also joined field trip activities with students. With respect to finding answers to my research questions, I believe I was aware of multiple contextual factors and multiple perspectives of participants in the classroom throughout the prolonged engagement.

**Persistent Observation**

The purpose of persistent observation is “to provide [depth] for researchers by helping them to identify the characteristics or aspects of the social scene that are
the most relevant to the particular question being pursued” (Tashakkori & Teddlie, 1998, p. 90). Lincoln and Guba (1985) state that “if prolonged engagement provides scope, persistent observation provides depth” (p. 304). Lincoln and Guba also suggest that the researcher can identify particular characteristics and elements (e.g., multiple influences, contextual factors) in the situation that are most relevant to the problem or issue being pursued and focusing on them in detail. I think this activity is more related to the quality of information I described. The long period of time with the teacher and students enabled me to see or identify some possible aspects or characteristics that were closely related to my research questions.

**Member Checks**

This is a process of “testing hypotheses, data, preliminary categories, and interpretations with members of the stakeholding groups from whom the original constructions were collected” (Guba & Lincoln, 1989, pp. 238-239). I used this technique both during the investigation and at its conclusion. I discussed my interview and observation transcripts with the teacher in order to make changes or corrections when necessary. Further, my analytic categories, conclusions, and interpretations were checked with the teacher prior to drawing my conclusions.

**Triangulation**

This is a technique used to establish the fact that the criterion of validity has been met. It involves the use of multiple data sources, multiple methods, multiple
As Patton (1990) explains,

One important way to strengthen a study design is through triangulation, or the combination of methodologies in the study of the same phenomena or programs. This can mean using several kinds of methods or data, including using both quantitative and qualitative approaches. (p. 187)

As mentioned previously, my data collection methods were a combination of observations, interviews, documents, and survey. Combining different kinds of data sources and methods provided cross-data validity checks (Patton, 1990) and reduced possible errors and biases that come from one particular method.

**Dependability**

Dependability (or consistency) is parallel to the conventional criterion of reliability that is concerned with the stability of the data over time (Guba & Lincoln, 1989). It focuses on "the process of the inquiry and the inquirer's responsibility for ensuring that the process was logical, traceable, and documented" (Schwandt, 1997, p. 164). In order to assess dependability, one technique is that the report should present as many of descriptions and actual words of the participants as possible (Bogdan & Biklen, 1992; Fraenkel & Wallen, 1996). Bogdan and Taylor (1975) described that "Qualitative research yields descriptions and quotations that are rich in imagery and that can convey to a reader an understanding of what a situation or person is like" (p. 145). This is one method of validating a qualitative research. Other techniques to ensure that results are dependable are triangulation and the descriptions
of the investigator's position. Triangulation strengthens dependability and credibility in terms of using a variety of methods of data collection and analysis (Merriam, 1998).

As I wrote the report, I tried to provide thick descriptions, direct quotations, and as much actual words of the participants as possible in order to ensure the consistency of my interpretations and inferences based on the evidence I collected over time throughout my study. In addition, I described the following things related to dependability: the assumptions, theory behind the study, my methodological perspective, my background and information, the basis for selecting informants and a description of them, and the social context from which data was collected.

Limitations

One limitation might come from a cultural factor based on the researcher's educational background. I have different educational experiences and points of view because I am most familiar with typical Korean science classrooms. For example, when I observed the science class, possible bias from my Korean cultural experience could influence and affect my field notes. However, my educational and professional experiences in the U.S. for 4 years could help overcome this limitation regarding my different educational and cultural background.

Another limitation could be related to the survey instrument. Regarding the Likert-type scales in the instrument, I used a continuum of 6 points ranging between extremes such as strongly disagree-strongly agree, and very trivial-very significant.
The interval of the 6 points is considered approximately equal in attitude or value loading. However, some rating errors can occur when some students are unfamiliar with or uncertain about what is being rated (Isaac & Michael, 1995). The interval on the 6-point continuum might be different because each student will respond with varying degrees of intensity to the item. In addition, because all 37 items in Part II of the instrument were worded in a positive direction, student responses could be biased by "over-rating" or "under-rating" the item (Isaac & Michael, 1995). Students who might be consistently biased in being favorably disposed in the positive statements may respond to items on only one side of the continuum.

Next, this study is limited to Mr. Fox's students at Lincoln Middle School. The results of the study are not generalizable to any middle school students outside the study. According to Lincoln and Guba (1985), transferability of my findings was confined to the specific participants and contexts. Naturalistic inquirers believe that it is impossible to make time- and context-free rules regarding human beings. That is, they argue that the generalization of findings is impossible, since there are always differences in context from situation to situation, and even the single situation differs over time (Borland, 1990; Guba & Lincoln, 1989; Lincoln & Guba, 1985).

Although the findings in this study are very limited in terms of transferability and applicability to similar conditions, generalizations may be made by the individual. Fraenkel and Wallen (1996) discussed generalization in qualitative research.
There is little question, we think, that generalization is possible in qualitative research. But it is a different type of generalization than that which is found in much quantitative research...In qualitative studies, ..., the researcher may also generalize, but it is much more likely that any generalizing to be done will be by interested practitioners – by individuals who are in situations similar to the one(s) investigated by the researcher. It is the practitioner, rather than the researcher, who judges the applicability of the researcher’s findings and conclusions, who determines whether the researcher’s findings fit his or her situation. (p. 465)

The final limitation of the study is that I was limited in the number of Mr. Fox’s classes that I could observe. I was limited to observing students in the second and fourth periods due to my schedule. I could not attend and observe the other students in other periods. In addition, there were no observations of the comparison classes.
CHAPTER 4

MR. FOX'S VIEWS ON EARTH SYSTEMS EDUCATION EXPERIENCES AND CHARACTERISTICS OF IESS CURRICULUM AND INSTRUCTION

Introduction

In Chapter 4, I describe evidence related to the following research purposes:

(1) to explore one teacher's views on Earth Systems Education experiences; and (2) to describe and document the nature and characteristics of the Integrated Earth Systems Science (IESS) curriculum provided by the teacher. The evidence presented in this chapter is based upon interviews with Mr. Fox, his responses to the written questions, classroom and field trip observations, analysis of documents, and my field notes from the observations.

Actual words of Mr. Fox and direct quotations from his responses to my written questions were primarily used to describe the teacher's views on ESE experiences. To report notable characteristics of the Integrated Earth Systems Science (IESS) curriculum provided by the teacher, I primarily examined documents.
and curriculum and instructional materials which closely correspond to the research question. Observations, field notes, and the survey (Part II) were also used to identify the characteristics.

Each section is organized by presenting the relevant research question, followed by analysis and interpretation of the data. Although the case study is written section-by-section for the sake of organization and convenience, in practice, it is difficult to separate Mr. Fox's views on ESE experiences and characteristics of IESS curriculum provided by the teacher into such categories. Thus, the evidence and interpretations in the chapter include both Mr. Fox's perspectives and the characteristics of the curriculum. According to the research questions and interview questions, this chapter describes Mr. Fox's views on: (1) ESE and its framework, (2) constructivism and instructional strategies, and (3) realities of implementing ESE. In addition, the characteristics of IESS are described in the last section of this chapter.

The following 2 sections: (1) Mr. Fox's Views on Earth Systems Education and the ESE Framework and (2) Mr. Fox's Views on ESE-Based Teaching and Learning Strategies, and their respective subsections pertain to Research question 1. Research question 1 is: What are the teacher's views on ESE, the framework of ESE, constructivism, and other components of IESS curriculum and instruction?

Mr. Fox's Views on Earth Systems Education and the ESE Framework

While interviewing and having discussions with Mr. Fox during this study, I realized that he was very happy with what he was doing and enjoyed teaching IESS
to eighth graders. In this section, I begin with his general views about ESE as an integrated science program. He explained that his integrated science curriculum was developed on the basis of Earth Systems Education and that ESE provided science educators with a conceptual approach to curriculum integration. Thus, major concepts and components of his school science curriculum were based on the Framework of the Seven Earth Systems Understandings. He stressed that the seventh grade curriculum emphasized more local topics and regional issues. In the eighth grade curriculum, the focus begins with local issues, then extends to a global perspective. He explained the structure and focus of the science curriculum.

**Written Question: What are your general perceptions about ESE as an integrated science program or curriculum?**

**Mr. Fox:** ESE provides a framework for developing and using an integrated science curriculum that can have a local focus. This was the basis for the development of our science curriculum for grades 7 and 8 at Lincoln Middle School. Our seventh graders study local examples of ecosystems and the impact humans have had on them. Along the way they learn about ecosystem dynamics, cycles of matter and energy, the importance and chemistry of water quality, population, waste management and natural resources. Focusing on local ecosystems and environmental concerns give the science curriculum a relevance it did not have before. Eighth grade students begin their year studying local drainage systems, including wetlands, and how humans can have an impact on them. Then they move on to more global topics, including climate change, plate tectonics and evolution. We try to integrate plate tectonics and evolution as much as possible. By focusing on topics of local and global importance, students study science in an integrated fashion. Aspects of all the sciences and even some social sciences are used to help students understand their local and global environment.
Next, when he was asked to explain the most important feature of ESE, he stressed the importance of providing local relevance in the curriculum as an important feature of ESE for students. His explanation:

**Written Question:** What do you think is the most important feature of ESE, compared to other science curriculum efforts or programs?

**Mr. Fox:** I think the most important parts of ESE for teachers include the flexibility and control (hence ownership) that teachers have with the curriculum. For students, it provides a relevance lacking in many other programs because it can have a local focus. Students also are involved in a variety of learning strategies. ESE can be used anywhere by teachers wanting to use their locality as a part of the curriculum. ESE also provides an integrated approach to the study of Earth that reflects the way most people view the world around them. ESE can help students become informed and thoughtful citizens.

With regard to his views on the Framework of the Seven Earth Systems Understandings (ESUs), he described that the seven understandings provide a wealth of opportunities for students to learn science. By looking at Earth as a set of interacting subsystems, students can realize that most of what is exciting and relevant in science is covered. It also includes the part that humans play in these interactions. By considering what humans do, students can become more informed citizens (based on Personal Communication, February 20, 2001). In addition, he said,

**The seven understandings can be used as a framework to develop a curriculum that integrates not only the science disciplines, but also social science, humanities, and math. The local and global issues we study include what governments are doing about them. The curriculum can have**
a community advocacy component. Our eighth graders are involved in a variety of service learning opportunities throughout the year, a part of which includes environmental community service.

I also asked him about any influence of the Framework on his curriculum and instruction. He stated,

They [ESUs] have been the basis of the decisions we have made on the topics we have chosen to teach. By focusing on topics that include interactions among the subsystems of land, air, water, ice and life, including human life, students learn science as they experience it. Science is taught as it is experienced, as an integrated subject.

Regarding his views on the Earth system approach at the middle school, Mr. Fox first described some major reasons that led him and his school to teach science using an Earth system approach. As he reflects in response to an interview question on February 27, 2001,

Mr. Lee: Could you explain all reasons or factors that led you to teach science with an Earth system approach or integrated science approach?

Mr. Fox: We used to teach life science in 7th grade and earth science in 8th grade. And, we became increasingly dissatisfied with the textbooks because of inaccuracies and also because there was little relevance for students. We were supplementing those books anyway. We just decided that the textbooks weren't appropriate for students. So, we adopted the Earth system approach. Some of us here (at school) have been involved in projects at The Ohio State University involving ESE, so we are quite familiar with the framework. We think now that what the student is doing is much more relevant, focusing especially in the 7th grade on local things going on in central Ohio, and even things going on in their own backyard in some cases. In 8th grade, we
continue that for maybe the first half of the year, and then we get into more global issues like climate change, change over time, plate tectonics, something like that. So, it [the curriculum] is strongly environmental and again because we live in the city, and around the city there are a lot of environmental problems. And, it's kind of a logical thing for us to focus on that. We are trying to make it relevant for the kids. And also, this is making the kids become good citizens, good participating citizens, too. So, that is an important part.

Interpretations

As Mayer (1995) suggested, Mr. Fox and other teachers in the middle school developed their IESS curriculum applying the conceptual framework and focus of ESE to curriculum integration. In the first interview, I realized that he has strong confidence and ownership as one of the developers of the IESS curriculum. He seemed to believe that he has been providing a really good opportunity for his students to learn about science within the context of the Earth systems. In addition, he appears to hold a positive attitude about his students’ efforts and achievements.

I think professionally we feel really good about what we are doing. Are we doing ESE as well as we can? No, I don't think so. We still have a ways to go. Of course, I think that's a sign about good teachers in general. Never really feel satisfied what they're doing. Always, they want to improve. So, I think we've got a good start. (Written Question)

As observed above, the framework of ESE was the basis of the decisions for the topics and units in the curriculum. ESE was incorporated into the IESS curriculum. For example, the focus of the seventh grade science curriculum begins with local issues and topics in the students’ local community and Ohio. The eighth
Graders delve further into both local and global issues, such as climate change, change over time, and El Nino. Mr. Fox's explanations are fairly consistent with the findings of the pilot study (see Chapter 3).

From his point of view, the most important feature of IESS was making science learning relevant to the students in their real world experience and real life environment. He believed that middle school students are constantly trying to make sense of the world around them. Therefore, he thought that the "science curriculum should have them consider their larger world (maybe just their community) and what is going on there is a good fit for them" (Personal Communication, February 20, 2001).

Mr. Fox's Views on ESE-Based Teaching and Learning Strategies

It is apparent from the review of literature that ESE teaching and learning strategies are very compatible with a constructivist perspective. In this subsection, I will consider Mr. Fox's views on constructivism and ESE-based instructional strategies. In an interview on February 27, 2001, Mr. Fox explained his views about constructivism.

Mr. Lee: What is your perception about constructivist ideas?

Mr. Fox: We do talk about constructivism. We try to organize things that we do. I try to make sure that kids are aware of that also. They need to know that there is a process that they have to go through. And part of that process is realizing that they already know about things. What they know may not be correct.
We start actually sometimes talking about ignorance. No one of us is stupid. All of us are ignorant. That's ok because everybody is ignorant, including me. And, ignorance is that you just do not know something ... you are not able to know something. No one is stupid, everybody is ignorant.

Mr. Fox: All people learn by adding information to an internal structure of knowledge. Information includes facts as well as ways of knowing and doing (process). It is important that students are aware of what they already know... that it could be incomplete or wrong. (Written Question)

While observing his classes, I could easily see that constructivist ideas were embedded in Mr. Fox's teaching activities. For instance, he always expressed the importance of the students' preexisting knowledge and beliefs. He said, "It is important that students are aware of what they already know and that it could be incomplete or wrong." He called them "naive notions," rather than misconceptions. He emphasized assessing students' naive notions and used several teaching strategies to determine his students' prior knowledge and possible misconceptions. He stated,

Mr. Fox: I have students assess these by group brainstorming and sharing and/or by the use of concept maps. This does not eliminate misconceptions but I think it identifies some of them. Constructivism also guides the learning process. Misconceptions often resemble early scientific hypotheses that have been disproved. By discussing these old ideas and showing how they were disproved helps students overcome their misconceptions. (Written Question)
Other constructivist ideas in his class are found in science topics and units in the IESS curriculum, authentic hands-on activities, field-based activities, field trips, and mini-projects. Detailed descriptions about these constructivist-based ideas will be described in other subsections in this chapter.

**ESE-Based Teaching and Learning Strategies**

Mr. Fox believed that ESE-based teaching and learning strategies work very well because they suit the learning styles of middle school students. With a focus on local places and issues, students are more engaged in what they study. He explained his major teaching strategies in response to the following question:

**Written Question:** What do you think about ESE-based teaching and learning strategies in your science class?

**Mr. Fox:** We use a variety of teaching strategies, all of which are compatible with ESE. These include group work (cooperative/collaborative learning), a jigsaw approach, inquiry, labs, activities, field trips—full day, and period long “walkabouts,” long term projects, videos, and Internet searches. I use concept mapping to either introduce an idea or to identify misconceptions or as a summary of what has been covered in a particular unit.

In addition, he described a long-term integrated project for the seventh graders.

**Mr. Fox:** Our seventh graders complete a long-term integrated project that includes them selecting a topic that may be environmental in nature. It includes tasks that are part of all curriculum areas and also has an advocacy component. Students are expected to do research from printed materials and also do an interview. Social studies (maps and current events), math
(data and graphs), language arts (edited paragraphs of information), and basic science concepts are all a part of the project. There also is an oral presentation.

Among those strategies, I asked him specifically about collaborative learning as I had observed that many classroom activities were designed for students to work as a group. According to Mr. Fox,

Group work allows students to use their strengths to contribute to some group product. The social negotiation of students working out who does what provides them with some ownership of what they do. The sharing of work and the sharing of information among themselves makes the learning more meaningful. This works best in mixed groups of students. I generally use rubrics to assess each student's individual contribution to the group and also the final product.

In addition to Mr. Fox's statements, students also expressed very positive attitudes about Mr. Fox's instructional strategies. For example, Items 18, 19, and 34 in the survey (Part II) relate to students' views about their teacher's style of teaching science and collaborative learning. As can be seen in Table 4.1, about 81% (Slightly Agree: 36.3%, Agree: 27.5%, Strongly Agree: 17.6%) of the students agreed that they liked Mr. Fox's styles of teaching science and the learning about activities he has provided (Item 34). With regard to Item 18, approximately 80% (Slightly Agree: 19.6%, Agree: 27.5%, Strongly Agree: 33.3%) of Mr. Fox's students agreed that interacting in a group with other students in science class helped them learn science.

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About 75% (Slightly Agree: 23.5%, Agree: 20.6%, Strongly Agree: 31.4%) of the students agreed with Item 19. It seemed that Mr. Fox's students preferred working in groups for learning science rather than working individually.

<table>
<thead>
<tr>
<th>Items</th>
<th>n</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Interacting in a group with other students helps me to learn science.</td>
<td>102</td>
<td>4 (3.9)</td>
<td>9 (8.8)</td>
<td>7 (6.9)</td>
<td>20 (19.6)</td>
<td>28 (27.5)</td>
<td>34 (33.3)</td>
</tr>
<tr>
<td>19. It is easier for me to learn science when I work in a team.</td>
<td>102</td>
<td>7 (6.9)</td>
<td>9 (8.8)</td>
<td>9 (8.8)</td>
<td>24 (23.5)</td>
<td>21 (20.6)</td>
<td>32 (31.4)</td>
</tr>
<tr>
<td>34. In our class, I like my science teacher's styles of teaching science and the learning about activities he has provided.</td>
<td>102</td>
<td>0 (0)</td>
<td>5 (4.9)</td>
<td>14 (13.7)</td>
<td>37 (36.3)</td>
<td>28 (27.5)</td>
<td>18 (17.6)</td>
</tr>
</tbody>
</table>

*Note.* Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA).

Table 4.1: Frequency and percentage distributions for items related to collaborative learning and the teacher's style of teaching.

**Assessment Strategies**

As I started my observations and document analysis, I realized that the teacher had well-organized grading policies and assessment strategies. In his syllabus, he had very distinct and clear grading policies.

All assignments/tests/projects are assigned a certain number of points depending upon their difficulty and the length of time needed to complete them. Tests are typically 100 to 120 points, quizzes about half that, projects a little more than a test grade, the notebook is 50 points per grading period and typical homework assignments and class activities are 3 to 6 points each. Late work is acceptable up to a deadline and will receive reduced
credit unless the student was absent. The grade for a student
each grading period is approximately 40% tests and quizzes, 20%
projects and 40% everything else. Grades are posted by student
number about every two and half weeks. Students can always
come in after school to check on grades. Generally, I do not
accept extra credit. I want students to do their best on the
"regular" credit. (Mr. Fox's Syllabus)

As he described in his syllabus, he used a variety of methods to assess
students' work (e.g., quizzes, open-ended questions, mini-projects, concept maps).
While I observed his class, Mr. Fox mentioned several times that using concept maps
is one important tool to assess students' understanding. He explained that "it is a
valuable tool for identifying misconceptions and for students to show how well they
see the big picture. Students and I are in the process of developing a room-sized
version of a concept map that represents the eighth grade curriculum." (See Figure
3.2.) In addition, he explained in the interview of February 20, 2001 that he has
students do projects as another type of evaluation method.

Mr. Lee: Do you have other types of evaluation methods?

Mr. Fox: Yes, we have kids do projects. Part of the projects
involve written components. I use a rubric for grading those. And,
part of it is oral presentations, sometimes kids by themselves,
sometimes by groups .... There are activities and some labs, and
these papers can be graded. That's part of assessment. Usually,
when kids are working in groups, I try to assess each individual's
contribution along with assessment of the group product. We try
to do both.
Interpretations

Mr. Fox's views about constructivism mirror his pedagogy. He believed that the students were actively seeking meaning based on their naïve notions. Therefore, he emphasized the importance of assessing students' prior knowledge. As observed above, he used several methods, including brainstorming and constructing concept maps, in order to determine prior knowledge and identify misconceptions. The use of these methods was evidence of one aspect of Mr. Fox's belief in constructivism.

Next, he believed that students should come to realize that they are basically responsible for their science learning. He mentioned that "The more they gather information for themselves and find out for themselves, the more meaningful their learning will be" (Personal Communication, February 27, 2001). Therefore, he was not totally dependent upon a lecture, a textbook, or cookbook laboratories. He used a variety of strategies in order to provide the best science learning to help his students develop their understanding of science. Cooperative learning techniques (e.g., jigsaw approach, group classroom activities) as well as real world, hands-on learning were primarily used in his classroom.

As Fortner (2002) stated, "grouping lessons not only helps students see the relationships between experiences but also assists in getting a wider array of information put before the students for real use" (p. 86). As presented in Table 4.1, students also agreed that collaborative learning in their class helps them learn science. In addition, several studies found that hands-on activities helped students 1) to achieve understanding about science and the environment, 2) to experience...
concepts and processes of the real world, and 3) to apply the principles to real world settings (LaPorte & Sanders, 1993; Wolfinger, 1994). Mr. Fox’s middle school had adopted constructivist-based ideas and the ESE framework in terms of student-centered learning where the teacher was more of a facilitator than a director.

Finally, Mr. Fox used a variety of assessment strategies. He used open-ended evaluations that allowed students to respond in several ways. Assessment in groups is done at times in the forms of group presentations. He also used oral presentations throughout students’ mini-projects and/or group projects as an assessment method. His rubrics and concept mapping were often used to keep students accountable. His instructional strategies were very compatible with ESE-based (constructivist-based) teaching and learning strategies and pedagogy. In addition, his beliefs were very consistent with students’ responses and descriptions stated in Chapter 5.

Realities of Implementing Earth Systems Education

This section pertains to Research question 2. Research question 2 is: What does the teacher perceive to be some of the benefits, barriers, and/or difficulties with teaching IESS?

Advantages (or Benefits) of the IESS Curriculum

When I asked Mr. Fox about student benefits (or advantages) from his IESS based curriculum, he first responded that the most notable benefit of the curriculum was that students had opportunities to connect their science learning to the real world
and to their daily life experiences. In addition, he stressed the flexibility of the IESS curriculum that promoted the use of a variety of teaching strategies, activities, and topics for students.

Mr. Fox: This is an advantage because we have the flexibility to choose activities from many different sources and to design our own. Many of these have a local focus. We also take students on two field trips a year to get them out into the ecosystems to study them. We often select topics that involve the interaction of one or more of Earth's subsystems. A perfect example of this is global climate change. It is a very complex interaction of air, land, and water and has been influenced by human activity. A modern day example we study that includes many things included in climate models is ENSO. By having some understanding of how ENSO works, students can get some insight into how climate might change. (Written Question)

As he stated in response to the written question, one of the key benefits in ESE is group collaboration for learning science. Through group projects, students can experience learning together, share information, and present their group work.

Written Question: In what ways do you think students benefit from your Integrated Earth Systems Science (IESS) curriculum?

Mr. Fox: They get to learn science as they experience it in the real world, as much as possible. The flexibility of the curriculum allows teachers to give students a "say" in what they learn (inquiry). Students experience a variety of teaching strategies and can use their own strengths to learn. They also work with other students from time to time in group activities. The social negotiation that occurs in groups reinforces learning.
When I observed his class, he mentioned to his students “I don’t want you to see science as a foreign language, simply memorizing a lot of words.” Mr. Fox wants science to be more meaningful and reasonable, and wants students to learn things to take with them through their life rather than something to memorize for a test (Observation, April 24, 2001). The most important benefit Mr. Fox thought is that the IESS curriculum can make science fun and enjoyable, helping students become happy learners.

**Barriers (or Difficulties) of Teaching IESS**

With regard to Mr. Fox’s views on any difficulties of IESS for teachers, he expressed two difficulties of teaching IESS: lack of a variety of teaching materials and teaching without a textbook.

Written Question: What do you perceive to be some of the barriers or difficulties in teaching with an Earth system approach?

Mr. Fox: It was a challenge at first to find a variety of teaching materials. We found several activities from many sources, including many things developed at Ohio State and have developed the rest ourselves. The school district has been very open about us developing and implementing our curriculum. A few parents have suggested that our curriculum lacks rigor. There have been, maybe, three parents in 10 years who have said so. We do not use a textbook so I emphasize to the students that their notebook is their textbook and they should do a good job writing it. I think this gives the students some control over what they do. We have had some concern from parents about not having a textbook because they may have a hard time helping their child...
with homework and the homework assignments don't look as well defined as an assignment with page numbers out of a textbook.

With regard to the textbook, he mentioned that not using a textbook could make new science teachers uncomfortable with teaching IESS. He said, "I suppose if I was a new teacher with no teaching experience and maybe didn't feel comfortable with a broad range of background knowledge, that's when a textbook would be nice" (Interview, May 23, 2001). Since the curriculum includes multi-disciplinary sciences of global change and other environmental issues, a new teacher may not teach IESS well if he or she does not have a strong base of Earth systems science content knowledge.

When I joined the class on a field trip to Big Darby Metro Park, Mr. Fox expressed that one barrier for ESE could be caused by the lack of enough time to be outside and discuss subjects first hand, instead of doing most of the discussions and instruction in a classroom environment. Therefore, he said, field trips are required in ESE to show students how unique Earth is because environmental components are mostly included in the domains of ESE (Personal Communication, April 23, 2001).

**Interpretations**

As stated above, Mr. Fox described several notable benefits of the IESS curriculum in the middle school. Based on the data from observations and interviews, one of the things I saw as an important benefit was that the IESS curriculum gave students many more natural ways than conventional programs to
make connections to the real world. Even though he mentioned that time-limitations for field experiences could be one barrier, he did help students make explicit connections between their science learning and the real world application during activities in the classroom. It would appear that his students had good opportunities to apply their science learning and knowledge to the real world or their immediate world (e.g., weather and environmental issues in their local community).

With regard to his teaching materials, some parents were not pleased because he did not use many traditional teaching methods and textbook-based lessons. Through observations, I found that his teaching materials for IESS were composed of a variety of hands-on activities rather than a textbook. Based on findings from the pilot study in Chapter 3 and students' responses to the written questions, I noticed that a lack of published materials and having no textbook were not challenges for the students. The students seemed to think that they have more benefits to learning science without a textbook (all student names in this study were replaced to protect the identity of those involved in the study).

Harold: I enjoy science class because we don't use a textbook. I like this method of learning because science changes everyday and textbooks would be outdated. I also like how we usually do experiments relating to every topic because I have a visual perception of how the topic works or happens. I think the reason I like science is very interesting and we learn it in more of a hands-on way instead of just reading it out of books, like we do in other classes.

Heidi: I like it [science] because we don't have to carry a textbook around with us all the time, and our teacher [Mr. Fox]
makes learning science so much fun. I also like when we do experiments.

Kathy: I like the way Mr. Fox teaches science and it is an easy subject for me to understand. I don't like learning from a textbook. I like doing things hands on.

Janet: My science teacher, Mr. Fox, is a very good teacher. He explains the topics we learn about thoroughly, so we can have a more clear understanding. Worksheets are much better than textbooks because we get to explore. Students usually tend not to read the textbook!

The IESS curriculum materials and Mr. Fox's instructional activities helped students learn real world-based science. I also identified having no textbook as one of the notable characteristics of the IESS curriculum provided by Mr. Fox. More detailed information regarding no textbook as one of the characteristics in the IESS will be described in the last section of this chapter.

Confirming one of the difficulties of teaching IESS as expressed by Mr. Fox was an interview with Dick on June 4, 2001. He pointed out that longer period field trips could be better to experience and do an activity.

Mr. Lee: What will you remember most about learning outside of school?

Dick: Probably Tar Hollow. Um, we were there for a longer time, you can experience, see more things there... If you go on a fieldtrip for a day it sort of seems like you're being rushed to accomplish everything you know on your agenda. But when you're there for a longer period of time, it's not as rushed. And in the activity where we compared all the fieldtrips and listed various species from each one we had found and Tar Hollow had by far the most species we had found because we'd been there longer.
But being there longer and seeing more species meant that we learned more.

While I observed the field trip for one-day, the students seemed to need more time to complete their activities and tasks.

Characteristics of the IESS Curriculum

This section and its respective subsections pertain to Research question 3. Research question 3 is: What are the characteristics of IESS curriculum and instruction?

During the pilot study, I realized that the IESS curriculum included several unique characteristics compared to other curricula. Therefore, I made a list of features of the IESS curriculum and instruction, and tried to create more opportunities to discuss the features with the teacher. Through the assistance of Mr. Fox, I was able to collect more data and evidence regarding the characteristics (e.g., curriculum materials for seventh graders, and guide book for the field trip) of the curriculum. In addition, the interview protocol used with students was based on these curriculum features.

This subsection first describes the units and topics in the ESE curriculum. Next, I describe the detailed information about field trips for both seventh and eighth graders, and then will explain about the teacher’s views on field trips, having no textbook, and mini-projects.
Units and Topics of the IESS Curriculum

While discussing his teaching strategies, Mr. Fox gave a brief history and listed the characteristics of all units and topics in his seventh grade and eighth grade curricula. The following question was asked in the interview of February 14, 2001:

Mr. Lee: Could you tell me how you determined the units and topics in your seventh and eighth curriculum in your school?

Mr. Fox: We chose the topics for our curriculum by using the ESE framework, trying to have all of the sciences represented, although most of what we do fits mainly into Earth science and life science, and wanting to have a local focus in the seventh grade, and to start the eighth grade with a local focus and go to a more global focus. We have made adjustments to our curriculum over the years and are getting ready to propose and discuss changes to it. We are doing this on our own volition and not as a result of a district directive. We have a lot of ownership of our curriculum.

Mr. Fox: Our curriculum was planned entirely by the three science teachers who were here 11 years ago. Two of us are still here. We were assisted in the process by being able to work with colleagues from other central Ohio school districts through an Eisenhower-funded grant. The grant also allowed us to explore a variety of curriculum materials and teaching strategies from which we chose what we do. The school district allowed us to make all of the decisions. We actually saved the district a considerable amount of money by not having to order textbooks, although we did order quite a bit of equipment. (Written Question)
In addition, he explained the major characteristics of his units and topics.

Written Question: Could you explain about characteristics of all units and topics?

Mr. Fox: Seventh graders study ecosystems, populations, solid waste issues (related to human population) and the use of natural resources. Eighth graders study drainage systems, wetlands, biodiversity, weather, climate and climate change, plate tectonics, evolution and Ohio natural resources. These topics all heavily involve the subsystems of air, water and life and occasionally ice and land.

As shown in Table 4.2, the topics and units strongly supported what Mr. Fox explained to me. IESS-based science topics and units are richly based on student’s real world experiences, local environments, classical and emergent environmental problems and scientific phenomena (e.g., biodiversity of the city of Lincoln, Ohio’s population, cycles in nature, drinking water for Franklin County, global warming, weather).

Exemplary Unit

As presented in Table 4.2, Mr. Fox is teaching a variety of locally- and globally-relevant scientific and environmental topics. As I worked with my observation data repeatedly, I was able to identify the teacher’s consistent instructional pattern and teaching sequence. He has a relatively simple pattern to teach most of the units.

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<table>
<thead>
<tr>
<th>Seventh Grade</th>
<th>Eighth Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Mapping/Leaves</td>
<td>• Drainage Systems</td>
</tr>
<tr>
<td>• Ecosystems</td>
<td></td>
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<tr>
<td>• Cycles in Nature</td>
<td>• Artificial – Storm Sewers, Sanitary</td>
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<tr>
<td>- Rock Cycle</td>
<td>• Natural – Streams, Watersheds,</td>
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<tr>
<td>- Nitrogen Cycle</td>
<td>• Contour Maps</td>
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<tr>
<td>- Carbon Cycle</td>
<td>• Human Influence</td>
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<tr>
<td>- Water Cycle</td>
<td>• Wetlands</td>
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<tr>
<td>• Microscope</td>
<td>• Estuaries, Pickerington Ponds, Food Webs</td>
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<tr>
<td>• Natural Resources</td>
<td></td>
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<tr>
<td>- Nuclear Energy</td>
<td>• Geology, Water Testing</td>
</tr>
<tr>
<td>- Biomass</td>
<td>• Human Influence</td>
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<tr>
<td>- Petroleum</td>
<td>• Groundwater</td>
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<td>- Natural Gas</td>
<td>• Water Movement, Human Influence</td>
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<tr>
<td>- Propane</td>
<td>• Biodiversity</td>
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<tr>
<td>- Ohio’s High Sulfur Coal</td>
<td>• Genetics, Species</td>
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<tr>
<td>• Population</td>
<td>• Effect of Humans on Biodiversity</td>
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<td>- U.S. Population</td>
<td>• Weather</td>
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<tr>
<td>- Ohio Population</td>
<td>• Global: Earth Motions, Sun,</td>
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<tr>
<td>• Solid Waste</td>
<td>• Rotation of Earth, Solar Energy,</td>
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<td></td>
<td>• Local: Air Masses, Fronts, Maps.</td>
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<td></td>
<td>• Change Through Time</td>
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<td></td>
<td>• Climate Change, Acid Rain</td>
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<td>• El Nino, Ozone Depletion</td>
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<td>• Volcanic eruptions, Plate tectonics</td>
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<td>• Evolution, Fossil Evidence,</td>
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<td>• Extinctions</td>
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<td>• Ohio’s Natural Resources</td>
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<td></td>
<td>• Ohio’s Geology</td>
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<td></td>
<td>• Natural Resources</td>
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<tr>
<td>Field trips</td>
<td></td>
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<tr>
<td>• Blacklick Metro Park</td>
<td>• Battelle-Darby Metro Park</td>
</tr>
<tr>
<td>(one day field trip)</td>
<td>(one day field trip)</td>
</tr>
<tr>
<td>• Trash tour of the county landfill</td>
<td>• Pickerington Ponds Metro Park</td>
</tr>
<tr>
<td>• Tar Hollow State Park</td>
<td>(one day field trip)</td>
</tr>
<tr>
<td>(three days field trips)</td>
<td></td>
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</table>

Table 4.2: Major science units and topics in the seventh and eighth grade.
First, he introduces new topics, and then shows videos, and finally has some demonstrations, or interesting things to motivate his students. Sometimes, he begins with asking the students some questions, doing brainstorming, or having students construct concept maps in order to identify their pre-existing knowledge and beliefs. Second, he explains activity instructions and introduces materials, references, and other detailed information related to the activity. Third, he lets students do the activities (usually group activities) and helps students do it well. He promotes a very interactive atmosphere, so students actively participate in generating new ideas and questions. While he is observing students’ activities, he is also evaluating students’ individual contributions to the group. Finally, students usually take open-ended quizzes, present their projects, or provide their portfolios. He evaluates students’ grades by using rubrics he designed, quizzes, and concept maps he made.

Among many topics in the eighth grade curriculum, I will describe one exemplary unit, El Niño. Even though this unit was a new topic to the teacher, students reported that El Niño was something they learned a lot about (see Section B of Chapter 5). Figure 4.1 shows the teacher’s instructional sequence and pattern when he taught El Niño. As I described previously, he first introduced the new topic, El Niño, and provided brief background information; for example, effects of El Niño on the weather in North and South America and other countries (e.g., Korea, Australia). Next, while students were watching a video program regarding El Niño, they were trying to answer the questions by using the study guide that the teacher prepared (see Appendix K).
Figure 4.1: Mr. Fox's instructional sequence and pattern for teaching El Niño.
On the second day, Mr. Fox and his students were talking about some content of the video. The teacher asked students to brainstorm to make their group research questions (see Appendix J). The teacher wrote down the questions that students proposed. Then, all questions on the board were categorized and synthesized into six categories. In addition, all students were divided into six groups according to their interests.

On the third day, the teacher provided some books, fact sheets, magazines, and articles that include direct information about El Niño. While students were doing group projects, I realized that they were very active participants in collecting information from the instructional materials or Internet to prepare their handouts and posters for group presentations (see Figure 4.2). During the group activities, the teacher was evaluating each student’s contribution to their group by using the El Niño rubric he designed to assess individual contributions (see Appendix K).

On the fourth day, students got started on their group presentations. After each presentation finished, the teacher took time to discuss or question the content or presentation. He also assessed the students’ presentations and handouts through the El Niño rubric he designed to assess group presentations (see Appendix K). On the last day of the El Niño class, the students took a quiz that included all open-ended questions (see Appendix K).

At the completion of the El Niño topic, I found that most students could explain about El Niño/La Niña and their global effects. They also learned about its history, how it forms, and its effects on the weather of their living place, the United
States and the world, their impacts and benefits, current El Niño/La Niña information, forecasts, and scientific data. In an informal conversation, I observed that most students correctly understood the nature of El Niño as a natural phenomenon.

Figure 4.2: Students’ posters used for group presentations about El Niño.

Figure 4.2: Students’ posters used for group presentations about El Niño.
Field Trips for Seventh Graders

According to the science curriculum, there are three field trips for seventh graders and two field trips for eighth graders. The first trip for seventh graders is to Blacklick Metro Park. The major purpose is to study three main ecological areas: forest, stream, and pond. Surveys of organisms, water quality, biological, chemical, and physical characteristics of a stream; and the geology of the area are examined. The second trip is a trash tour of the county landfill, a wastewater treatment facility, and a compost plant. Students get a first-hand look at how humans deal with solid and liquid wastes. The third trip is a three-day outdoor education camp at Tar Hollow State Park. Mr. Fox said that this trip has been done for 47 years. During this study, I did not have a chance to join the first and second field trips for seventh graders because Mr. Fox was only teaching eighth grade students. However, I had an opportunity to observe the third field trip because Mr. Fox helped other teachers for the two night camping programs at the state park. Even though I observed this nature study camp for only one day, I realized that this trip provided students with a very good opportunity to learn and appreciate nature and the need to conserve it.

There are several notable features I noticed. First, students benefited from a very interesting bus field trip along the way. While they were on their way to the park, the school bus stopped at 30 different places to take a rest and to look at specific features more closely. As students traveled along, each listed feature was pointed out by name and number. In most cases, students had at least one question or statement to read and respond to for each feature. According to the bus trip guide, the
major content in the bus trip focused on the roadside evidence of glaciers in Ohio, rocks, geologic features and structure, landfill, and plants. Table 4.3 shows two questions and statements (6 and 13) in the bus field guide book. The findings obtained from this bus tour were also used as materials for other activities in the field trip, such as Glaciers in Ohio, and Traveling the Ohio-Erie Canal.

The second notable feature of the camp trip is that students had the opportunity to get close to nature. They slept in cabins in the woods, they hiked along trails with flowers and budding trees, and they enjoyed fishing at a pond. They had the chance to smell, see, touch, and hear all of the things around them.

BUS TRIP GUIDE –LINCOLN, OHIO TO CAMP TAR HOLLOW, OHIO

6. 0.7 MILE FROM SITE 5 – EAST SIDE OF ROUTE 23 JUST NORTH OF SCIOTO DOWNS. THESE LARGE “BUMPY” HILLS ARE TYPICAL OF GLACIALLY DEPOSITED SAND AND GRAVEL. THE ILLUSTRATION BELOW SHOW HOW THESE HILLS FORMED.

DIAGRAM (A) SHOWS THESE FEATURES IN THE PROCESS OF FORMATION. THE ICE ACTS AS TEMPORARY WALLS WHILE SEDIMENT IS DEPOSITED BY MELT-WATER STREAMS. AFTER THE ICE MELTS, THE SEDIMENT IS LAID DOWN ON THE GROUND, LEAVING WHAT WE SEE TODAY (DIAGRAM B).

(omission of diagrams)

THE FEATURES HERE AT SCIOTO DOWNS ARE KAMES. IF THEY WERE FORMED IN OR ALONGSIDE THE ICE, WHY ARE THEY NOW HILLS THAT STAND ABOVE EVERYTHING AROUND THEM?

(6-1) (A) THEY ERODED AWAY (B) THE ICE MELTED (C) THE STREAMS DISAPPEARED

Table 4.3: Example of questions and statements from bus trip guide.
Table 4.3 (continued)

13. 4.1 MILES FROM SITE 12 – REST STOP ON THE WEST SIDE OF ROUTE 23-STRETCHING OFF TO THE EAST IS A RELATIVELY FLAT AREA COATED WITH TILL. CONSEQUENTLY, IT IS CALLED A TILL PLAIN. THE LONG RIDGE THAT STARTS AT THE REST STOP AND CONTINUES TO THE WEST AND SOUTH IS AN OUTWASH DEPOSIT. IT WAS FORMED BY A STREAM FLOWING IN A TUNNEL UNDER THE ICE. (Look to the illustration for Site 6 to find out its name.)

**WHAT IS THIS FEATURE CALLED?**

(13-1) (A) KAME  (B) KETTLE  (C) ESKER  (D) DRUMLIN

**ESKERS ARE LONG AND NARROW AND WIND BACK AND FORTH ACROSS THE LANDSCAPE, WHY?**

(13-2) (A) STREAMS MEANDER  (B) THEY WERE LOST  (C) THE ICE MELTED

THIS PARTICULAR ESKER IS KNOWN AS THE CIRCLEVILLE ESKER. IT EXTENDS FROM HERE TO JUST NORTH OF CIRCLEVILLE.

BEHIND AND JUST A LITTLE NORTH OF THE REST AREA IS AN ABANDONED SAND AND GRAVEL PIT THAT WAS EXCAVATED IN THE CIRCLEVILLE ESKER.

**THIS ESKER IS COMPOSED OF WHAT TYPE OF SEDIMENT?**

(13-3) (A) SILT & CLAY  (B) CLAY & SAND  (C) SAND & GRAVEL

**CIRCLE THE LETTERS OF THE CHARACTERISTICS THAT DESCRIBE THE ROCKS HERE IN THE GRAVEL PIT**

(13-4) (A) MULTI-COLORED  (B) STRIPED  (C) BLACK AND WHITE  (D) DULL COLORED  (E) GRAY  (F) BROWN

**WHERE DID THE NON-OHIO ROCKS COME FROM?**

(13-5) (A) CANADA  (B) AKRON  (C) PITTSBURGH  (D) KENTUCKY

**HOW DID THESE NON-OHIO ROCKS TRAVEL TO OHIO?**

(13-6) (A) TRUCK  (B) RAILROAD  (C) GLACIER  (D) STREAM
The third notable feature of the camp trip is the array of planned projects and activities. Each morning and afternoon, interesting activities were planned for the students. For instance, during the first day project (which they called combined Bus/Lake and Stream activities), students compared and contrasted the meadow environment with the forest environment. Students walked down the middle of a stream to the lake and looked for interesting animal and plant life. The teachers provided the following 13 different types of science activities on the first day: (a) The Rise and Fall of the Ohio Canals, (b) Traveling the Ohio-Erie Canal, (c) Glaciers in Ohio, (d) The Logan Elm, (e) Be a City Planner, (f) Adapting to an Environment, (g) Collect and Observe Amphibian Eggs, (h) Collect and Observe a Salamander or Crayfish, (i) Rocks at Tar Hollow, (j) Collect and Observe Three Water Insects, (k) Can You Ride a Water Cycle?, (l) Whatever the Weather, and (m) Check Out the Stream. Before students started these activities, they hiked in the stream bed, observed the plant and animal life dependent on the water environment, and saw how water is carving away the land. The hike ended at the human-made lake, Pine Lake, for recreation and water control. At the end of the hike, students could select several activities and follow the instructions on the related guides. For example, Activity (j), Collect and Observe Three Water Insects, used the insect specimens collected on the hike. Students discovered some interesting information about them (see Table 4.4).
COLLECT AND OBSERVE THREE WATER INSECTS

No camping trip would be complete without taking a close look at the many insects which inhabit the area. Water insects are easily found at Camp Tar Hollow, and observation of these animals will give you an opportunity to see interactions among organisms in their habitat.

FOR THIS ACTIVITY YOU ARE TO DO THE FOLLOWING

1. Collect three or more water insects or insect larvae-use nets, containers to dip, or be quick of hand. 2. Using the books available, identify the insects you have collected.

<table>
<thead>
<tr>
<th>INSECT # 1</th>
<th>INSECT # 2</th>
<th>INSECT # 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name</td>
<td>Name</td>
</tr>
<tr>
<td>Location collected:</td>
<td>Location collected:</td>
<td>Location collected:</td>
</tr>
<tr>
<td>Description:</td>
<td>Description:</td>
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<td>Color</td>
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<td>Protective Devices</td>
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<td>Shape</td>
<td>Shape</td>
<td>Shape</td>
</tr>
<tr>
<td>Markings</td>
<td>Markings</td>
<td>Markings</td>
</tr>
<tr>
<td>Source of Food</td>
<td>Source of Food</td>
<td>Source of Food</td>
</tr>
<tr>
<td>Length of</td>
<td>Length of</td>
<td>Length of</td>
</tr>
<tr>
<td>Time in water</td>
<td>Time in water</td>
<td>Time in water</td>
</tr>
</tbody>
</table>

Stage insects are in (circle one) Stage insects are in (circle one) Stage insects are in (circle one)

EGG LARVAE EGG LARVAE EGG LARVAE
PUPA ADULT PUPA ADULT PUPA ADULT

Sketch your insect below Sketch your insect below Sketch your insect below

List Titles and Pages of any books used on back of this sheet:

FOR EXTRA CREDIT–Mount your specimens with pins or glue (-be sure to label)
Field Trips for Eighth Graders

Eighth graders also go on two field trips. The first trip is to Pickerington Ponds Metro Park, a glacially-formed wetland that has been significantly modified by humans and continues to be threatened by development. Students study the biology and chemistry of the pond, a succession area, and how both are impacted by the geology. The second trip is a service learning trip to clean up a stream and monitor the water quality of the stream (see Appendix K). The site, Battelle-Darby Metro Park, is in the city. A part of the trip is a discussion of human impact on the site and how human awareness of the plants and animals that live there can be heightened. During my observation period, I joined the second field trip to the Battelle-Darby Metro Park.

Before the trip, students were divided into three groups because they were supposed to work with three topics at three different areas: Area A: Stream Life and Water Quality, Area B: Stream Characteristics, and Area C: Nature Trail Walkabout.

First, students collected water insects from the stream (see Figure 4.3) to use with the Stream Quality Assessment Form. I redrew one section in the form to show the result filled out by one student (see Table 4.5). In Area A there were two major activities to assess water quality.
Second, students were assigned several physical and chemical tests to perform on a sample of the stream water. They used the test kits and thermometers to collect the following data to assess water quality: pH, dissolved oxygen, nitrates, phosphates, hardness, water temperature, and air temperature. Activities around Area B included three parts: Part I. Rock identification, Part II. Mapping the stream bed, and Part III. Calculating the velocity of the stream. During students' visit to Area B, they identified the different types of rocks that were found in the stream bed. They also were asked to figure out where the rocks originated and to make a profile of the stream based on the measure of the depth and the width of the stream.
Table 4.5: Example from one section in the Stream Quality Assessment Form.

In addition, students calculated the area of the stream in profile and stream velocity. As can be seen in Figure 4.4, students were actively engaged. They were eager to learn and were actively involved in what was happening. In the final Area C, students looked for the organisms living along the nature trail and surrounding the wetlands, and recorded the ones that they found. In addition, they took small soil samples from the succession area near the trail for chemical analysis upon returning to school.
Mini-Projects

Each student developed two oral presentations about any science topics that interested them. Mr. Fox told me that the students are not allowed to present on any topics they had covered in class or would cover the rest of this school year. When I asked him about any repetition of topics, he responded that,

Some reservations we have about these projects are the repetition and recycling of topics over the years and the roles parents sometimes play in the projects. As we review our curriculum later this year we will decide how we will change/improve the way we have students do these projects.
In his syllabus, Mr. Fox provided detailed information about the mini-projects and oral presentations as follows:

**STUDENT PROJECTS**

Students will develop an oral presentation (mini-project) on a science topic of their choice in each of the first and fourth grading periods. The presentation will be videotaped outside of school, or at school in front of the class or to Mr. Fox. Each presentation will last four to five minutes and will be supported by a variety of visuals that could include poster(s), Astound-based material, and/or actual objects. Specifications of the expectations for mini-projects will be given to students. These projects will be due at a time scheduled by each student and all will be completed by one week before the end of the grading period (first and fourth) in which it is assigned. If a student does not complete a project on time, parents will be notified immediately.

During the second and first part of the third grading periods, students will develop and present either an invention project or a science fair project. These will be presented by all eighth grade students at the Invention Fair that is scheduled this year on Thursday, March 8, 2001. Class presentations of these projects will take place that same week starting on Monday, March 5, 2001.

He also expressed some benefits from the mini-projects.

The mini-projects allow students an opportunity to pursue information about a topic they are interested in. They also have students plan how to share the information they have collected. The invention or science fair project allows students to express their creativity in terms of the scientific method or in developing or improving upon an invention. (Written Question)
In order to assess the mini-projects, he used a simple evaluation form and provided comments or suggestions about students' oral presentations (see Table 4.6).

<table>
<thead>
<tr>
<th>Science Grade 8 Oral Presentation Evaluation – 150 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Fox (Comments/Suggestions on back)</td>
</tr>
</tbody>
</table>

Name _________________________________ Per _______

1. Appropriate amount of material presented. _____ out of 25 pts.
2. Accuracy of the material presented. _____ out of 25 pts.
   (includes knowledge of material)
3. Material well organized. _____ out of 25 pts.
4. Appropriate visual aid and explanation of it. _____ out of 30 pts.
5. Good use of "reminders" like note cards. _____ out of 30 pts.
6. Make eye contact with "audience". _____ out of 15 pts.

Date ________________ Audience ______________________
Total points ________ out of 150. Topic _____________________

(back side)
Comments/Suggestions

The comments that have been "checked" relate to your presentation.

_______ Don't read your notes so much — use them more as a "quick reference."
_______ You need a greater variety of things on your visual(s).
_______ Refer to your visual(s) more often throughout your presentation.
_______ Things on your visual(s) are too small for your audience to see clearly.
_______ Good use of notes.
_______ Very nice visual(s).
_______ Good use of visual(s).

Other Comments:

Table 4.6: Oral presentation evaluation form.
In summary, it seems that the mini-projects gave students good opportunities to explore science topics, to gather information, and to share it in an oral presentation by using visuals. The teacher also provided productive and useful feedback and comments to the students through the evaluation form.

No Textbook

As I described in the findings from the pilot study, students make their own textbook by using instructional materials provided by the teacher. In an interview with Mr. Fox on May 20, 2001, he explained,

Mr. Lee: I think, they [students] made their own textbook.

Mr. Fox: Yes, That's how I approach it. Their notebook is their textbook. I have talked with students many times throughout the year. Especially, I told them at the beginning of the year to make sure they understand all the things we do. They are writing their textbook. They need to do a good job of that. And I do grade notebooks. I think kids handle (the way I have them do notebooks) that pretty well. Parents sometimes have a problem about that. But, I think kids handle it very well in terms of not having other books to carry all the time.

Mr. Lee: I think your resources are very excellent compared to other textbooks. And, what instructional resources do you use for science class? I know some video materials...

Mr. Fox: And the GEMS' materials [Great Explorations in Math and Science], SEPUP [Science Education for Public Understanding Program], ACES [Activities for the Changing Earth System]. Some of things are from EAGLS [Earth Systems-Education Activities for Great Lakes Schools] through a Sea Grant.
Because they have no official textbook, students' notebooks were considered valuable materials in this science class. I realized that the most significant material in the classroom was the student's own notebook that functioned as the textbook. In fact, the students were not permitted to remove pages from their notebook just as they would not tear pages out of a textbook. The students also liked to study science with the teacher's instructional materials rather than the textbook-based materials (see Chapter 5).

**Interpretations**

Throughout the study, I found several noteworthy characteristics of IESS curriculum and instruction. The first is the array of units and topics in the curriculum; ESE focuses on locally-relevant topics at the beginning leading to a global perspective. As observed in Table 4.2, Mr. Fox tried to focus on local examples of each topic, especially in the seventh grade and the beginning of eighth grade. The IESS curriculum also includes global level issues for eighth graders. In other words, the major content includes topics that address the most important issues of the day at the local, regional, and global levels. For instance, the students study such local issues as the changing Metro Parks and the human impact on them, how acid rain affects the place where they live, and how humans have altered the local watershed and environment. Other topics include global climate change, rainforest
destruction, wetland destruction, and ozone depletion. Those units and topics reflect the major themes of the Seven Earth Systems Understandings, such as human influence and interacting subsystems.

With regard to the exemplary unit, students were very interested in learning about El Niño. In this unit, the students learned about the processes of El Niño, worldwide effects, human influence, scientists' research and efforts to predict this natural phenomenon. In an interview with Jeff on May 23, 2001, he addressed the reason he chose El Niño as his favorite unit:

Mr. Lee: Can you tell me why you like El Niño?

Jeff: Well I liked learning about it because it has to do with ocean stuff and that's kind of neat because you don't get to learn that much of it because there's no ocean around here and you got to learn how it worked and the different phenomenon's that were in it that you didn't know about before.

When Mr. Fox taught this unit, he used several instructional methods, such as brainstorming, cooperative learning (group work and group oral presentations), and alternative assessment. It seemed that those methods were all based on ESE teaching strategies. In addition, he had consistent pattern and sequence to teach IESS (see Figure 4.1).

The second noteworthy characteristic of the IESS curriculum is the inclusion of field trips for both seventh and eighth grades. ESE has proposed the use of extensive fieldwork in the local community as one science teaching method that is consistent with establishing the climate of inquiry emphasized in the National
Science Education Standards (Mayer & Tokuyama, 2002). Rudman (1994) explains that field trips can serve as tools for increasing the opportunities for students to improve their process and thinking skills and enhance interest in science learning. In addition, field trips also connect the school curriculum to the local environment and link cognitive and affective aspects of learning. Field trips provide an opportunity for observations, direct experience with nature and all materials, short investigations, and group discussions (Dori & Tal, 2000; Tal, 2001).

According to the evidence presented in the previous section, all activities in the field trips were designed for integrating the science disciplines or other subject areas (e.g., mathematics, language arts), and making curriculum connections between science and the real world environments. In the interview of April 23, 2001, Mr. Fox stated,

> When we visit a field trip site, students consider the geology, biology and chemistry, parts of the subsystems there. Class work also includes as many science areas as possible as we discuss what is happening at the edges of subsystems.

The field trips included excellent hands-on experiences for students. Students' responses indicated that they preferred to learn science through hands-on methods (see Chapter 5). While I observed two field trips, it was apparent that Mr. Fox really enjoyed teaching science on the field trips.

> A day in the field is better than the best day in the classroom. Students get to see what they are studying instead of trying to simulate it in some way. I get to teach in a way that makes the most sense - by doing things at the source. It is the ultimate hands-on experience. (Written Question)
The third noteworthy characteristic is the inclusion of mini-projects. According to Moje, Collazo, Carrillo, and Marx (2001), "Project-based pedagogy engages children in textual and experimental inquiry about authentic questions...affords students and teachers opportunities to investigate, talk, read, and write about questions of interest to them" (pp. 469-470). Recently, several reports and studies indicate that school projects have attempted to engage students in real world science learning experiences through inquiry-based projects based on interesting topics and questions (Goldman, 1997; Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998; Merino & Hammond, 1998; Moje et al., 2001).

Mr. Fox's mini-projects have been designed to provide students with extensive and authentic science learning experiences. From the beginning to end of the mini-projects, students gain experience with a variety of skills: information-searching skills (e.g., using the Internet); organizational techniques; communication skills; and presentation skills. The National Research Council (1996) recommends project-based learning and mini-projects as excellent ways to learn science (see the Mini-Project section in the Chapter 5).

Finally, Mr. Fox did not use a textbook. Throughout my observations, I realized that Mr. Fox has tried to find good resources and activities, and then to use appropriate materials from many sources that include locally relevant or globally extended topics and content. Thus, he believed that students' notebooks could not be replaced by any formal textbook.
CHAPTER 5

STUDENTS' VIEWS AND UNDERSTANDINGS ABOUT THE INTEGRATED EARTH SYSTEMS SCIENCE EXPERIENCE

The purpose of Chapter 5 is 1) to highlight what has been learned about students' views of IESS-based science learning and the characteristics of the IESS curriculum and instruction described in Chapter 4; 2) to explore students' understandings regarding the framework of ESE; and 3) to compare students' self-reported knowledge, self-perceived significance levels of 13 Earth systems and environmental topics, and primary information sources about the 13 environmental topics with a comparison group.

The evidence presented in this chapter is primarily based upon interviews with students, results from the survey (Parts I and II), classroom observations, and my field notes. To examine student views on the curriculum and instruction, some semi-structured interview questions were used with the students. The survey data were also used to explore students' self-reported knowledge about the ESUs, and to compare the knowledge and significance scores on 13 Earth systems and environmental topics and 23 Earth systems concepts and topics with the comparison...
group. In addition, students’ responses from related items in Part II of the survey instrument are assigned a numerical value, and the total item score is calculated by summing the numerical responses given to each item. Similar items were grouped together by the researcher. The total number of responses and the frequency for each item is presented to describe students’ views toward the IESS curriculum and instruction. Each section is organized by presenting the research question followed by analysis and interpretation of the relevant data. Chapter 5 is organized into two sections:

Section A: Students’ Views on the IESS Curriculum and Instruction
Section B: Students’ Understanding of the Framework of ESE and Earth Systems and Environmental Topics

Section A: Students’ Views on the IESS Curriculum and Instruction

Section A pertains to Research question 4: What are students’ views about the characteristics of the IESS curriculum, instruction, evaluation, instructional materials, field trips, and mini-projects?

In Section A, I primarily deal with students’ views on each of the characteristics of IESS identified and described in Chapter 4 and several other matters that emerged gradually throughout my observations, interviews with the students, and analysis of student notebooks. I focus on the following matters: student
views of IESS content, Mr. Fox's teaching style and instructional strategies, assessment methods, field trips, mini-projects, and instructional materials (including having no textbook). I present qualitative and quantitative evidence found in the study, followed by an interpretation.

Students’ Views on Science Content

The intent of this subsection is to document students’ views on science content they have learned and their favorite unit or topic. Selected evidence from interviews with several students, descriptive data from the survey (Part II), and observations were used to examine student’s views about IESS content.

The following evidence is from interviews with four students: Dick, Jeff, Angelis, and Carol (all student names in this study were replaced to protect the identity of those involved in the study). Due to my semi-structured interview format, the questions asked of students were similar.

Dick was a bright and quiet student who had a very good grade in science. The teacher informed me that Dick was one of the smartest students in the class. In an open conversation, I asked him about his opinion about science class and the topics covered. He replied “I enjoy it because it deals with everyday life, such as weather and pollution, so it makes it easier to relate to than other classes. It’s also more common sense than some other classes” (Personal Communication, May 17, 2001). At the end of the school year, I interviewed him on June 4, 2001.
Mr. Lee: What is your favorite unit or topic in science class this year?

Dick: I'll say weather. We learned about different air masses and I've seen on television you know this [these] fronts moving through but I never really understood what that meant at all and this year, you know, we would explain to it how it all works so now it, actually, when it rains now, I could tell what kind of front's going through by the kind of rain.

Mr. Lee: Do you have another topic or unit you like?

Dick: Oh, I enjoyed the whole thing.

Mr. Lee: Generally, what do you think about the units and topics that you have learned about?

Dick: I think it's very interesting the things that, when you're younger, go on just right outside your life but you never really know the detail and you sort of accept they're there but you don't really understand what they're about. And I think this year, we particularly learned why things happen the way they do.

Jeff was a basketball player in the school. He was a fun, very tall, active student. When he was involved in group activities, he always led the group members and performed very well during the activity. In an interview on May 23, 2001, he explained about his favorite unit or topic during the academic year.

Mr. Lee: What is your favorite unit or topic in science class this year?

Jeff: Um, it's probably hard to say, but I liked El Niño just because I kind of knew what it was but I didn't understand how it
worked. Um, I liked learning about wetlands and all the things in
them because they're all around us.

Mr. Lee: Yeah, can you explain why you liked the wetland unit?

Jeff: Um, Why I care about wetland is because our friends have
a wetland because they own a farm and it was fun to learn what
could be in their wetland, and the next time we go I can look for
stuff and know more about it.

Mr. Lee: Generally, what do you think about the units and topics
that you have learned about?

Jeff: I like learning about it and um... I like learning and just
understanding it more than I knew before. Especially with El
Niño, because I didn't know anything about it.

Angelis is a tall and shy girl. Based upon an opportunity to join her group and
work along with them, I felt she enjoyed doing experiments. She mentioned, “I like
how we usually do experiments relating to every topic because I have a visual
perception of how the topic works or happens” (Personal Communication, May 1,
2001). She emphasized the importance of topics related to plate tectonics and
learning through the experiments. In an interview on May 23, 2001, Angelis explains
why she likes the topic of plate tectonics.

Mr. Lee: What is your favorite unit or topic in science class this
year?

Angelis: Um. I think I liked plate tectonics.

Mr. Lee: Angelis, Tell me why you like plate tectonics.
Angelis: I don't know. I was just sort of interested in the way the Earth moved and how things were formed and how things worked and how volcanoes are formed and stuff like that.

Mr. Lee: Is there another topic or unit you like?

Angelis: I just like science a lot. I can't really pick out another one that I specifically like.

Mr. Lee: Generally, what do you think about units and topics that you have learned about?

Angelis: They're good topics and it's a good curriculum for 8th grade year. Sort of gets us ready for the things we're gonna learn next year and also intertwines with the things we learned last year.

Carol was a very bright and active girl. While all students were watching a science video program, she sometimes made a funny face and made other students smile. But, when she presented a science project, I realized that she did her best and did a good job. In one conversation with her about science class and the topics covered, she said, "I like this science class because you get to learn new stuff that you did not know about the Earth systems and other topics" (Personal Communication, May 18, 2001). Carol responded to my interview questions regarding science content. In the interview of May 18, 2001, Carol indicated that she liked the topics of genetics and weather because these topics directly related to her life.
Mr. Lee: What is your favorite unit or topic in science class this year?

Carol: Um, probably genetics.

Mr. Lee: Carol, tell me why you like genetics?

Carol: I just think it's really interesting how things are created related to humans so I just find that topic very interesting.

Mr. Lee: Do you have any other topics you like?

Carol: I pretty much like everything but genetics is pretty much my favorite.

Mr. Lee: Can you tell me your second favorite?

Carol: Probably learning about weather and climate and stuff.....Like weather and cold fronts and stuff.

Me: Why did you like the weather unit?

Carol: Because we live through weather everyday and I'd like to know how it's been formed and created.

Mr. Lee: Generally, what do you think about the units and topics that you have learned about?

Carol: I think we learned good topics because every topic we learned has a direct effect on us. So I just believe that science is really important to us as a person.

Additional evidence is based on the results of the survey. Items 6, 12, 22, and 23 (Part II) were designed to assess students' views on IESS-based science content. Frequency and percentage distributions for these items were used to report the results of the survey. Results are reported in order of the highest percentage of agreement or
disagreement with the item. As shown in Table 5.1, approximately 81% (Slightly Agree: 25.5%, Agree: 35.3%, Strongly Agree: 20.6%) of Mr. Fox’s students agreed that their science classes would help them make good decisions in the future (Item 23). For Item 22, about 70% (Slightly Agree: 25.5%, Agree: 29.4%, Strongly Agree: 15.7%) of the students agreed that what they have learned from science class was important to their everyday life. With regard to Item 6, about 68% (Slightly Agree:

<table>
<thead>
<tr>
<th>Items</th>
<th>n</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. I like to use actual environmental problems and phenomena to learn about science in science class (e.g., El Niño, Ozone Hole, Global warming).</td>
<td>102</td>
<td>7</td>
<td>9</td>
<td>16</td>
<td>26</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td>12. I would prefer to learn about science from a global perspective rather than from local examples.</td>
<td>102</td>
<td>14</td>
<td>8</td>
<td>22</td>
<td>20</td>
<td>11</td>
<td>27</td>
</tr>
<tr>
<td>22. Many of the things we have studied in science class are important to my everyday life.</td>
<td>102</td>
<td>4</td>
<td>9</td>
<td>17</td>
<td>26</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>23. What we have done in science class will help me make good decisions in the future about environmental problems such as global warming.</td>
<td>102</td>
<td>4</td>
<td>2</td>
<td>13</td>
<td>26</td>
<td>36</td>
<td>21</td>
</tr>
</tbody>
</table>

Note. Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA).

Table 5.1: Frequency and percentage distributions for items related to science content and topics.
25.5%, Agree: 26.5%, Strongly Agree: 16.7%) of the students agreed that they liked environmental problems and phenomena as science units and topics. However, responses to Item 12 indicated that only about 56% (Slightly Agree: 19.6%, Agree: 10.8%, Strongly Agree: 26.5%) of the students preferred to learn about science from local examples rather than a global perspective.

**Interpretations**

On the basis of constructivist learning theory, ESE provides authentic classroom activities based on students' real world experiences. As presented in Table 4.2, ESE science topics and units in the middle school are richly based on student's real world experiences, local environments, traditional and emergent environmental problems and science phenomena (e.g., biodiversity of the city of Lincoln, Ohio's population, cycles in nature, drinking water for the county, global warming, weather, etc.). In the interview with Carol, she clearly responded that science topics they have studied learned had direct effects on her life. Dick also expressed the importance of learning science related to his life. In addition, about 70% of the students agreed with Item 6. These results indicate that what students have learned in science class are associated and connected with their everyday lives. In particular, about 81% of students agreed with Item 23, "What we have done in science class will help me make good decisions in the future about environmental problems such as global warming." It seems that IESS based science activities not only provide integrated
and locally relevant knowledge for students, but also offers sufficient opportunities for students to apply subject matter to their everyday lives. However, approximately half of the students (56%) would prefer to learn about science from a global perspective rather than from local examples (see Item 12 on Table 5.1). The next subsection discusses students’ views on assessment methods and grading.

**Students' Views on Grading Systems and Concept Mapping**

Throughout my observations, interviews, and document analysis, I realized that the teacher had well-prepared assessment methods. As described in Chapter 4, the teacher expressed the importance of using concept maps to help determine students’ understanding and knowledge. In order to explore students’ views on using concept maps as one of the assessment methods, the concept maps in their notebooks and interviews with students were used as evidence. In this subsection, I describe what students thought about the grading methods, focusing on concept maps and Mr. Fox’s way of assessing work to determine grades. The relationship of these results to constructivist theory is also noted.

The results come from the survey (Part II) described at the beginning of this subsection. Items 25, 33, and 37 group under students’ views of the grading system and concept mapping. Frequency and percentage distributions for those items are shown in Table 5.2. Results are reported in order of the highest percentage of agreement or disagreement with the item. For Item 37 related to Mr. Fox’s way of
assessment, approximately 77% (Slightly Agree: 32.4%, Agree: 26.5%, Strongly Agree: 18.6%) of Mr. Fox's students agreed that the teacher's grading system, including tests, quizzes, homework assignments, and projects, was fair and satisfying. Regarding Item 25, approximately 62% (Slightly Agree: 24.5%, Agree: 19.6%, Strongly Agree: 18.6%) of the students agreed to some degree that “drawing concept maps in science class helps me to put science concepts (or ideas) together.” However, the results for Item 33 related to the concept maps is somewhat different than expected. More specifically, students responded nearly equally between some degree of agreement (nearly 54%) and some degree of disagreement (approximately 46%). Students' responses were mixed in terms of their belief in the use of concept maps in quizzes and tests to assess their knowledge.

<table>
<thead>
<tr>
<th>Items</th>
<th>n</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25. Drawing concept maps in science class helps me to put science</td>
<td>102</td>
<td>14</td>
<td>14</td>
<td>10</td>
<td>25</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>concepts (or ideas) together.</td>
<td></td>
<td>(13.7)</td>
<td>(13.7)</td>
<td>(9.8)</td>
<td>(24.5)</td>
<td>(19.6)</td>
<td>(18.6)</td>
</tr>
<tr>
<td>33. Using concept maps in my quizzes and tests is an appropriate</td>
<td>102</td>
<td>10</td>
<td>20</td>
<td>17</td>
<td>20</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>method to assess my knowledge.</td>
<td></td>
<td>(9.8)</td>
<td>(19.6)</td>
<td>(16.7)</td>
<td>(19.6)</td>
<td>(18.6)</td>
<td>(15.7)</td>
</tr>
<tr>
<td>37. My science teacher's way of assessing my grade is fair and</td>
<td>102</td>
<td>1</td>
<td>7</td>
<td>15</td>
<td>33</td>
<td>27</td>
<td>19</td>
</tr>
<tr>
<td>satisfying.</td>
<td></td>
<td>(1.0)</td>
<td>(6.9)</td>
<td>(14.7)</td>
<td>(32.4)</td>
<td>(26.5)</td>
<td>(18.6)</td>
</tr>
</tbody>
</table>

*Note.* Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA).

Table 5.2: Frequency and percentage distributions for items related to assessment methods and concept mapping.
I expected that students who got a grade of A in science more strongly agreed with Items 25 and 33, so I explored the frequency of students’ choice on the two items according to their science grade (see Table 5.3) and any possible relationship between students’ science grade and their choice (Pearson product-moment correlation technique = $r$, with at least 95% confidence level). The results indicate that there is no significant relationship between student’s science grade and student’s choice on either Items 25 or 33. However, there is a very strong and positive relationship between Items 25 and 33 ($r = .88, p < 0.01$).

<table>
<thead>
<tr>
<th>Scale</th>
<th>Item 25</th>
<th>Item 33</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GRADE</td>
<td>GRADE</td>
</tr>
<tr>
<td></td>
<td>A B C D</td>
<td>Total (%)</td>
</tr>
<tr>
<td>1</td>
<td>7 7 2 2</td>
<td>14 (13.7)</td>
</tr>
<tr>
<td>2</td>
<td>6 6 2 2</td>
<td>14 (13.7)</td>
</tr>
<tr>
<td>3</td>
<td>3 7 3 1</td>
<td>10 (9.8)</td>
</tr>
<tr>
<td>4</td>
<td>11 12 2</td>
<td>25 (24.5)</td>
</tr>
<tr>
<td>5</td>
<td>8 9 2 1</td>
<td>20 (19.6)</td>
</tr>
<tr>
<td>6</td>
<td>8 7 3 1</td>
<td>19 (18.6)</td>
</tr>
<tr>
<td>Total</td>
<td>43 48 9 2</td>
<td>102 (100)</td>
</tr>
</tbody>
</table>

*Note.* Each item has a 6-point scale where 1 means strongly disagree and 6 means strongly agree.

Table 5.3: Number of students on each rating scale of 1-6 on Items 25 and 33 related to their science grade.

On May 17, 2001, I conducted interviews with several students regarding the teacher’s grading and the use of concept maps. First, both Dick and Jeff liked the
teacher's grading system and the construction of concept maps as alternative assessments. Dick mentioned that, although the concept maps were a little time consuming, he thought the strength of concept maps was the importance of seeing the whole picture and the connections of concepts within the topic. Jeff also responded that the concept map was a way to connect all the things they learned about. The following are selected parts of the interviews:

Mr. Lee: What do you think about his way of assessing your grade?

Dick: I think he does a pretty good job of grading. He grades for completion. I don't see a lot of problems with his grading system.

Mr. Lee: Do you like using concept maps?

Dick: Yes I do, I think you get all these different terms and different things that are going on in an unit and you may understand them individually, but you can never fully understand them until you can see the whole picture and how they all relate to each other and maybe you know two separate things, but you don't know how they relate and I think the concept map just puts everything together so you can see the whole picture and how everything relates.

Mr. Lee: Did you enjoy this when you drew the concept map?

Dick: It's a little time consuming, you have to think a lot, but when you're done, you have basically an outline of how everything works in that topic.

The interviews with students related to Mr. Fox's assessment of their grades and the use of concept maps were conducted on May 23, 2001.

Mr. Lee: What do you think about his way of assessing your grade?

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Jeff: I think it's fair because he doesn't really decide your grade, you decide your grade and I mean if you do all the right things, do all your homework and do your projects well then you're gonna get a good grade. So the harder you work the better grade you're gonna get.

Mr. Lee: What about concept maps?

Jeff: Um, I wasn't familiar with it before this year but I like it because it's a way to connect all the things we learned about...Here we did this with all the things we learned about this year and it's a way to connect them all instead of having separate things. We can connect everything together.

Mr. Lee: Do concept maps help put ideas together?

Jeff: Um, yeah you can put your ideas together and see how everything works as a whole.

In contrast to the responses of Dick and Jeff, the following three students, Judy, Carol, and Tom, thought concept mapping was not a lot of fun and not important to their science learning. In addition, some of the students thought concept mapping took too long to do and involved tedious attention to details.

Judy was very bright and knew a lot about science. The teacher informed me that she has maintained a good academic standing due to her hard work. Although she has had a good grade, she did not fully understand why the use of concept maps helped her conceptual understanding. I interviewed Judy on May 18, 2001.

Mr. Lee: What do you think about his way of assessing your grade?
Judy: He does good, that's what I think and um... The only thing different from his class and other classes is a 94 is A, 93 is an A-, and in other classes, a 92 is an A- and 93 is still an A. But I've had an A in his class every single time so it doesn't really affect me.

Mr. Lee: He uses many different ways to assess your grade. For example, concept mapping. Do you like concept maps?

Judy: Oh well, it's not hard work, but it's tedious. You know it's just boring stuff... keep drawing and connecting things and telling why. I don't really like concept maps, it takes too long.

Mr. Lee: Can you tell me another reason why you hate concept maps?

Judy: It takes too long and I don't understand why it helps us. I mean, who cares if it has to do with this or if it has to do with that. It's just, I mean, I think in my mind I know which has to do with each other. But I don't like drawing it out and everything.

Another student, Carol, responded in her interview of May 18, 2001 that she did not have much of an opinion about concept maps. However, she was satisfied with Mr. Fox's way of determining grades.

Mr. Lee: What do you think about his way of assessing your grade?

Carol: I think the way we're graded is really good because we're graded on completion so it has less pressure on us. We learn it to know it by heart. That's what the tests are for so I like the way how he grades for completion on homework assignments.

Mr. Lee: What do you think of concept maps?

Carol: I don't really like it. I don't know much about it.
Mr. Lee: Can you tell me why you hate it?

Carol: I don't hate it. I just like the normal way I guess. I don't know.

Mr. Lee: Then, do you think that drawing concept maps help put ideas together?

Carol: Yeah, it's pretty much how much we have learned of how to connect ideas together.

Another student, Tom, was very thin and quiet guy. He was very interested in the weather unit. When he was asked in his interview of May 22, 2001 what he thought of the concept mapping, he responded in a somewhat negative manner based on the grading of the concept maps.

Mr. Lee: Mr. Fox uses many different ways to assess your grade. For example, concept mapping. What do you think about concept maps?

Tom: I don't really like concept maps.

Mr. Lee: Why?

Tom: Like, concept map, you have to have the, like, the exact right answer. Like in quizzes or tests when we have to do concept map like I'll forget like one line and he'll take 2 points off for just one line.

Mr. Lee: But the teacher provides main terms and concepts that you need to connect. Is it still difficult?

Tom: I normally get it. It's just like sometimes, I miss like one or two.
Interpretations

There are several studies to suggest that concept mapping could promote conceptual understanding in the science classrooms (Jegede, Alaiyemola, & Okebukola, 1990; Novak, Gowin, & Johansen, 1983; Zieneddine, & Abd-El-Khallick, 2001). In contrast, some limited research indicates that there are no significant differences in terms of conceptual understanding between students who used concept maps and those who did not in the context of laboratory experiences (Markow & Lonning, 1998; Stensvold & Wilson, 1990). The evidence related to the survey and interviews in the current study support the latter conclusion. For example, for Item 33, about half the students agreed and about half the students disagreed with the use of concept maps to assess their knowledge.

Furthermore, student interviews were also divided in their reaction to the use of concept maps. The responses from Dick and Jeff reflected some advantages to using concept maps in their science class, whereas Judy, Carol, and Tom did not like the concept maps as an assessment method. According to Tom, he disliked Mr. Fox's way of grading the concept map. In the interview with Carol, she clearly did not have much of an opinion about the concept map. And, Judy expressed her feeling that constructing concept maps was tedious and not helpful. To gain for their insight into student feelings about concept maps, I looked at the examples of concept maps in Judy's and Carol's notebooks (see Figures 5.1 and 5.2).
Figure 5.1: Judy's concept map about weather. (Redrawn)

Even though Judy is not very interested in concept mapping, her concept map reveals linkages between concepts and explanations that are well correlated with the weather topic. The teacher gave her a high concept map score even though she did not complete the map perfectly. In contrast, Figure 5.2 shows that Carol's concept map seems to indicate a lack of understanding of the concepts. She got 16 points out
of 20 points due to lack of proficiency in connecting two of the concepts, air masses and winds. Other concepts were also not well connected on the map.

Figure 5.2: Carol’s concept map about weather. (Redrawn)

After I looked at other students’ concept maps in their notebooks, I realized that it was a little difficult to determine the specific reasons why students were
divided in their reaction to the concept map as an appropriate way to assess their knowledge. However, from interviews with other students on June 4, 2001, it would appear that the students were already aware of the advantages of constructing concept maps.

Mr. Lee: What do you think about concept mapping generally? Do you like concept maps?

Adam: It helps me think how everything like goes together. Sometimes concept mapping is a little difficult, like, to make connections.

Angelis: I think those are sort of easy for me. It's helpful and it's also a good thing to know how to do ... We can use them later on in life, like we can use them like in high school or doing something when you put everything together in order and how each thing affects another thing.

Dianne: Oh yeah! When you use, like draw lines of things like this ... it like shows that all our topics, they all go together. It makes sense ... If you understand and you like are practicing and you like learn listening and understand what's going on in the class, then, it's easy. Kind of like when you link things together. It's easier to remember.

Eilene: (pause) Um. actually, I kind of like those because it make you think randomly because you don't get to know the terms. You have to like look at them and think about it, But some of them are kind of hard .... It's alright.

In summary, although students recognized some advantages or benefits of using concept maps in their science class, it appears that students were divided in
their views of using the concept map as an evaluation tool. However, the survey result showed that a majority of students were very satisfied with the teacher's way of assessing their grades.

*Students’ Views on Characteristics of the IESS Curriculum and Instruction*

In this subsection, I examine students' views on field trips, mini-projects, and the instructional materials identified as characteristic of IESS curriculum and instruction in Chapter 4.

*Students’ Views on the Field Trips*

After I observed two field trips and interviewed the teacher and students about field trips, it became apparent that the field trips have influenced students' science learning about Earth systems and nature. I was able to obtain evidence through interviews and observations. The following is an interview with Angelis on May 23, 2001 regarding field trips.

*Mr. Lee:* Which one [among field trips] did you like best?

*Angelis:* I liked Big Darby Metro Park because we got to go into the creek and get hands on and doing a lot of stuff and I just like doing things hands on getting into the creek. It was a lot of fun.

*Mr. Lee:* What did you experience on the trip?

*Angelis:* I learned a lot about animals, rocks in the creeks and the animals that are healthy for the creeks like that live in healthy creeks and stuff so that was really helpful.

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Mr. Lee: Could you have learned the same things in class?

Angelis: Yeah probably but not as well. It wouldn't be stuck in our mind, we would sort of ignore it probably.

Mr. Lee: What will you remember most about learning outside of school?

Angelis: Um, I'll probably remember.. It was fun. We had fun while we were doing it.

Angelis emphasized the importance of learning through hands-on based field trips. She mentioned that the field trip made it fun and enjoyable. Another student, Judy, had a similar response in her interview of May 18, 2001.

Mr. Lee: Which field trip did you enjoy?

Judy: Yeah, probably Tar Hollow.

Mr. Lee: What did you experience on the trip?

Judy: We saw nature and we saw how different species and where they live, and the meadows, the forest, things like that and umm...cause Tar Hollow was water... biodiversity.

Mr. Lee: Did you do any science activity there?

Judy: It was all science. All learning about different animals.

Mr. Lee: Could you have learned the same things in class?

Judy: Well, I mean you could but, it's better to actually learn it hands-on you know, really see it, cause if you just learn it, you
just learn it. But if you go and actually see and do things it makes it a lot better, it's easier to learn, it's funner that way.

**Mr. Lee:** What will you remember most about learning outside of school?

**Judy:** Probably that it was easier, I'll remember that it's easier. It's because, it's, you're not just looking at things from one point of view, you get different points of view and you remember it because it's, it's funner that way...and I don't know, when things are fun, you remember.

From Judy's responses, it would appear that she found learning through hands-on and field-based activities easier than learning in a classroom. In a class observation, I talked with her about the field trip again. She believed that learning from the field trips was something different because she could learn from doing, observing, examining, and experiencing things in the real world (Personal Communication, May 23, 2001). I realized that the hands-on learning experience throughout the field trips allowed her to learn science in a different way.

Another student, Dick, also liked the field trip to Tar Hollow because he had three days of nature study and liked camping experiences. He said he still had good memories of the friends he made, the wonderful field trip sites, and the great times that he had. He also expressed the importance of hands-on experience for learning nature. In an interview with Dick on May 17, 2001, I obtained the following evidence.
Mr. Lee: Which one [among field trips] did you like best?

Dick: I'd probably have to say Tar Hollow. It was sort of away from it all. Normal field trips, you go out there for a few hours, you can still sort of see man made things and you go home right afterwards so it's more short term. But Tar Hollow you were there for a few days and I like camping, so that's probably also had something to do with it. You were just always in nature so you were always learning something like whether you were consciously aware of it or not. You were always seeing something in nature and seeing how it is related to you.

Mr. Lee: Did you do science activities?

Dick: Yes we did live science activities on all the fieldtrips. We did different tests on the water and different species that are in the water and we went on various hikes that you'd explore the kinds of plants that were there. And it was actually interesting to learn what kind of plant... like if you point out this one, it will help a bug bite.

Mr. Lee: Could you have learned the same things in class?

Dick: Not really. You couldn't have experienced it like you did there. I mean you can learn different plant's names and stuff, but most kids would look at it and plug it in their minds for the test but forget about it right away. If you see a plant in nature, chances are, you're gonna remember it.

The following results from the survey corroborated Mr. Fox's students' remarks regarding the field trips. Items 26 and 27 relate to students' attitudes toward field trips. As shown in Table 5.4, about 83% (Slightly Agree: 20.6%, Agree: 26.5%, Strongly Agree: 36.3%) of the students agreed that field trips helped them
understand science topics and content that they have learned in science class.

Moreover, over 80% (Slightly Agree: 17.6%, Agree: 21.6%, Strongly Agree: 42.2%) of the students agreed that the field trips they have taken this year have been an important part of science class (Item 26).

<table>
<thead>
<tr>
<th>Items</th>
<th>n</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26. The field trips we have taken this year have been an important</td>
<td>102</td>
<td>43</td>
<td>22</td>
<td>18</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>27. Science field trips help me understand the local environmental and science concepts that I have learned</td>
<td>102</td>
<td>37</td>
<td>27</td>
<td>21</td>
<td>10</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

*Note. Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA).*

Table 5.4: Frequency and percentage distributions for items related to field trips.

**Students' Views on the Mini-Projects**

As I described in Chapter 4, students can select any topic in science and get a chance to present their mini-projects with the aid of visual materials (e.g., poster, actual materials, transparency). After I observed students’ oral presentations based upon self-selected topics for their mini-projects, I noticed several notable features related to the mini-projects. First, students enjoyed the mini-projects because they learned about a topic that they weren’t forced to study. Therefore, they had much
freedom in choosing topics. Students seemed to like that they were allowed to choose their own topics. When asked, students described a variety of topics they had chosen for their mini-projects.

Mr. Lee: I know you can select any science topic. What is your topic?

Dick: The most recent one I did was on the Wright Brothers. The development of airplane.

Adam: Sports injuries.

Dianne: What was my topic? You were there during yesterday... Koala bear.

Jeff: I did mine about new golf clubs that have a trampoline in the back where there’s a real thin face and it just trampoline’s off and they’re illegal so I did the project about how the trampoline works and it was really interesting.

Eilene: Um... my most recent topic? I did how humans can transmit bacteria from one person to another.

Judy: My topic was umm... rate of chemical reactions....

Mr. Lee: Rate?

Judy: Rate like how fast the chemicals react towards each other.

Mr. Lee: What kind of chemicals?

Judy: Chemicals like iodine. Yeah, it’s confusing chemicals. I like chemistry.

Carol: I did the panda bear.

Angelis: Last time I did malaria and I also did Albert Einstein.
Second, the mini-projects provided opportunities to expand on what students knew. They could learn more about their own topics of interest because students explored science topics that would not be covered in class. In the following interviews, students expressed what they enjoyed about the mini-projects.

Mr. Lee: What did you enjoy about your mini-project?

Dick: I enjoyed learning about how the airplane came about because I thought it was cool to fly. We’d go to North Carolina every few years and I’ve seen where the Wright Brothers actually flew their airplane (Kitty Hawk) and I just thought that it might be something interesting to research since I never really knew exactly what happened.

Adam: Learning how to prevent injuries because I get a lot of them and seeing how injuries can happen.

Dianne: Umm...because it was something that I was interested in. It wasn’t like it was assigned. It was something that I wanted to learn more about, and advance my knowledge in it.

Jeff: I enjoyed that I got to learn about something that I like to do since I like to play golf. I got to learn about golf clubs so that was a lot of fun.

Eilene: Well, um, I enjoyed the fact that you can pick whatever you want because my dad’s a doctor and I think that’s what I want to be so both of my projects have been more medical related. So it makes it a lot more enjoyable.

Judy: I like...it was fun to do all the experiments I got to do. I don’t know, but just really interested in it.
Third, students had ample opportunity to increase their computer skills by Internet searching using popular software, word processing, and sometimes doing presentations. As can be seen from the following interviews, students spent much time searching for information and knowledge for their mini-projects using the Internet. In addition, while students were preparing for their oral presentations, they gained experience using various types of resources and learned how to manage, organize, and present their data and findings. In the following interviews, the students explain how they prepared for their presentations.

Mr. Lee: How did you prepare for your presentation?

Dick: I started with gathering research from different sources, Internet and books. I got a video and went through the information and sort of came up with a timeline of main key events and I sort of worked that into, I guess you can say, a script of what I wanted to communicate and the important key events that led to the development of the airplane and then I basically came upon pictures that would match with all the events and went through and made a video of me talking about things and pointing out pictures that related to it.

Angelis: Um, I used a poster board. I got information from the Internet and books.

Dianne: Um...I practiced at home. And umm...I made sure all my resources are like, had good information.

Mr. Lee: Where did you get your resources?

Dianne: Most are from, I got some from the library and I got
some from the Internet.

Mr. Lee: In the school library?

Dianne: Public library and some from the Internet.

Carol: I wrote a lot of information. Then I took notes on the information, organized it into a report. Then I added visuals that are related to my topic.

Jeff: Um, well over a few weeks I gathered research from the Internet and the US Golf Association website about it and different club makers about it. And then on a poster board, I drew a picture of how it works and I put some other pictures on there and then I wrote a script and I did the presentation. That's pretty much how I prepared for it.

Eilene: Um...well, I talked to my dad a lot and he gave me some pamphlets and some websites and also since I had this topic in mind; I had done an experiment similar to this a couple of years ago, and so I just took a lot of different resources.

Judy: I researched a bunch of stuff about how chemicals react towards each other and which chemicals like um... what kind of reactions they have, how fast they react, and I got a book and stuff, and Mr. Fox and another science teacher from the high school gave me chemicals to work with. I made like graphs and things.

As shown in Table 5.5, Items 24 and 35 (Part II) are designed to assess students' views on mini-projects in science class. Frequency and percentage distributions for these items were used to report the results of the survey. For Item
24, about 87% (Slightly Agree: 23.5%, Agree: 36.5%, Strongly Agree: 27.5%) of Mr. Fox’s students agreed to some degree that mini-projects and activities in science class were helpful in learning Earth-related science topics. Approximately 87% (Slightly Agree: 18.6%, Agree: 28.4%, Strongly Agree: 40.2%) of the students agreed to some degree that their mini-projects are very helpful in learning other science topics (Item 35).

<table>
<thead>
<tr>
<th>Items</th>
<th>n</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24. Working on projects (including mini-projects) and activities in science class helps me learn about Earth and science</td>
<td>102</td>
<td>3 (2.9)</td>
<td>1 (1.0)</td>
<td>9 (8.8)</td>
<td>24 (23.5)</td>
<td>37 (36.5)</td>
<td>28 (27.5)</td>
</tr>
<tr>
<td>35. My mini-projects on a science topic of my choice are very helpful in learning other science topics.</td>
<td>102</td>
<td>0 (0)</td>
<td>4 (3.9)</td>
<td>9 (8.8)</td>
<td>19 (18.6)</td>
<td>29 (28.4)</td>
<td>41 (40.2)</td>
</tr>
</tbody>
</table>

*Note.* Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA).

Table 5.5: Frequency and percentage distributions for items related to mini-projects.

**Students' Views on Instructional Materials**

During the pilot study, I noticed that students seemed to like Mr. Fox’s instructional materials and handouts. Throughout my observations, I also felt that Mr. Fox tried to provide good instructional materials and handouts. When the students were asked what they thought about the instructional materials and having no textbook, most responded that they liked the teacher's materials better than a
textbook. Students seemed to like different varieties of topics and experiments. It would appear that they didn't like learning science the same way for every topic as provided in a typical textbook. In interviews with students, they expressed the following views on their instructional materials.

Mr. Lee: I know you have no textbook. But, your teacher provides handouts, activities, and materials. What do you think about the instructional materials?

Dick: Um, I think it's more exciting learning without a textbook. I think the textbook is sort of boring and you learn the words and you learn what actually happens where. Unless you do an experiment and actual hands on things, you don't really understand exactly what happens and I personally like having just the handout and doing activities instead of using textbooks.

Adam: I like it [teacher's materials] better because it makes you read through the whole things, so he gives it to you and you read through it, and like in a textbook, you're just assigned a page to read. You know all you have to read is that page. I learn more with handout paper.

Angelis: I like those [teacher's materials] better than the textbooks because textbooks, you just sort if read and you do stuff about them, but this way you can read the worksheets and you can do that, but you don't always have to just read the textbook and do the same thing everyday. You can do something different.

Dianne: They're good, like everything is from, like, college professors and stuff, and it's not a whole bunch of stuff we have to read through. It's kind of like he explains each thing we do, an activity on every piece of paper we get.
Mr. Lee: What do you think about having no textbook?

Dianne: Yeah, I like it, cause it's not assignments like in a book and it's like in your notebook...stuff that you've already written, like ideas that you take a note of.

Eilene: I like it [teacher's materials] because like some subjects where you do kind of have to have a textbook, like math and stuff. And it's nice to have to have a class where it's more free.

Judy: I think he does good, because we don't have to learn it just however it's said in the book, you know, he makes it so that it's more interesting and more ...you can expand on certain things and you're not so limited.

Mr. Lee: What do you think about having no textbook?

Judy: Yeah, it's good not having a textbook.

The other evidence is based on the results of the survey. Frequency and percentage distributions for these items were used to report the results of the survey. Results are reported in order of the highest percentage of agreement or disagreement with the item. Items 13 and 36 (Part II) are designed to assess students' view on using a textbook. As shown in Table 5.6, approximately 85% (Slightly Agree: 25.5%, Agree: 35.3%, Strongly Agree: 24.5%) of Mr. Fox's students agreed to some degree that instructional materials provided by the teacher were more efficient than a textbook (Item 36). More than 80% (Slightly Agree: 9.9%, Agree: 7.9%, Strongly Agree: 62.4%) of the students agreed with Item 13. They did not like to use a textbook to learn science.
Table 5.6: Frequency and percentage distributions for items related to students' views on using a textbook.

Interpretations

Regarding student views on field trips as an integral part of the IESS curriculum, Orion (1993) has suggested, "the main role of the field trip in the learning process is the direct experience with concrete phenomena and materials" (p. 325). Several studies have also provided convincing evidence that field trips are beneficial, especially when the students have more interesting hands-on experiences (Folkomer, 1981; MacKenzie & White, 1982; Orion, 1993; Orion & Hofstein, 1994; Vinci, 1969). As observed in Chapter 4, a variety of science process skills were used in hands-on activities during the field trips. For example, in the field trip at the Darby Metro Park, students were able to gain direct experience with the following process skills: (a) identifying water insects, animals, and plant; (b) measuring the depth,
width, and speed to make a profile of stream; (c) interpreting data and calculating volume; and (d) observing and testing rocks and soils, then comparing the findings (see Appendix L). These process skills were used to achieve the objective of hands-on activities. According to Angelis, Judy, and Dick, hands-on experience and science process skills in the field trips were very helpful in learning science and understanding the local environment. They also expressed that science learning through hands-on, field trips was fun and very interesting to them. They were able to better understand the concepts throughout the activities. In addition, the survey results also supported the idea that field trips, as a part of the curriculum, are useful and helpful for students.

Second, three features of the mini-projects were identified as valuable based upon the interviews, observations, and documents analysis: (a) students' discretion in selecting topics, (b) extensive science learning throughout the project, and (c) learning science along with Internet and computer skills. Based on the evidence in the previous section, students enjoyed their topics, including the process of preparation (handouts, posters, or other visuals) and their oral presentations. The mini-projects provided good opportunities for students to learn about other science areas and assisted students in understanding additional Earth systems and science concepts.

Finally, regarding students' views on instructional materials and not having a textbook, the findings indicate that resources and activities provided by Mr. Fox
They not only enjoyed the instructional materials, but also enjoyed the science learning because those materials focus on more locally-relevant or globally-extended content.

Section B: Students' Understanding of the Framework of ESE and Earth Systems and Environmental Topics

This second section presents findings associated with students' self-reported understandings about major concepts and themes regarding the Framework of Seven Earth Systems Understandings, self-reported knowledge and self-perceived levels of 13 Earth systems and environmental topics, and students' primary information sources on the 13 topics. There results are related to Research question 5: What are students' perceptions of the major concepts and themes within the ESE framework?

A multivariate analysis, Wilks's lambda, was used to determine the significance level of mean differences between Mr. Fox's students and comparison students for the dependent variables. MANOVAs were conducted for the following three sets derived from Part I of the survey: (1) self-reported knowledge and self-perceived significance levels of 13 selected Earth systems and environmental topics, (2) self-reported knowledge level of 23 Earth systems concepts and topics, and (3) self-perceived significance level of 23 Earth systems concepts and topics.

In accordance with guidelines provided by Klockars and Sax (1986), significance was determined at the 95% confidence level ($p = 0.05/3 = .017$)
corrected by Bonferroni's inequality principle for all univariate analyses. Table 5.7 provides the results of the multivariate analysis of variance. Of all the analyses, the values of Wilks's lambda for the first MANOVA ($\Lambda = .258$, $F_{1,192} = 18.48, p < .000$) and second MANOVA ($\Lambda = .737$, $F_{1,192} = 2.52, p < .000$) are significant.

Regarding the third MANOVA, the value of Wilks's lambda is not significant. This result implies there is no linear combination of the dependent variables that significantly separates the two groups.

In this section, each of the follow-up univariate analyses for self-reported knowledge and significance are presented for Mr. Fox's students and comparison students. In addition, frequency and percentage distributions for related items in the survey (Part II) are also reported.

<table>
<thead>
<tr>
<th>Set of Variables</th>
<th>Wilks's lambda</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Self-reported knowledge and self-perceived significance levels of 13 selected Earth systems and environmental topics</td>
<td>.258</td>
<td>18.48***</td>
<td>.000</td>
</tr>
<tr>
<td>2. Self-reported knowledge level of 23 Earth systems concepts and topics</td>
<td>.737</td>
<td>2.52***</td>
<td>.000</td>
</tr>
<tr>
<td>3. Self-perceived significance level of 23 Earth systems concepts and topics</td>
<td>.958</td>
<td>.31</td>
<td>.999</td>
</tr>
</tbody>
</table>

*Note.* Significance determined at $\alpha = .05$.

***$p < .000$.  

Table 5.7: Results of MANOVA for three sets in Part I of the survey.
Students' Understanding of the Framework for ESE

As described in Chapter 2, the framework for Earth Systems Education consisting of seven understandings provides a basis for science teachers to construct an integrated science curriculum. The IESS curriculum was developed on the basis of the framework. Therefore, it seemed desirable to explore students’ understanding of ideas and themes of the framework. Quantitative data from the survey instrument has been used to examine students’ understandings in this section.

Earth Systems Understanding#1 (ESU#1)

This first understanding emphasizes the aesthetic values of planet Earth as interpreted in art, music, and literature and appreciation of the Earth (Mayer, 1989). This understanding is quite different than expectations found in traditional science curriculum frameworks. Before the survey, it was expected that Mr. Fox’s students would have higher self-reported knowledge mean scores because their IESS curriculum and Mr. Fox’s instructional activities reflect an appreciation and value of the Earth. During my observations, I also felt that students seemed to recognize esthetic qualities of Earth systems and an aesthetic appreciation throughout the field trips. As described in Chapter 4, related to the field trip to Tar Hollow, I noticed that students had an excellent opportunity to learn about Earth systems and appreciate nature while they were doing activities, such as hiking along trails with flowers and budding trees and fishing at a pond.

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In the survey, Items 1, 2, 3, and 14 (Part II) are designed to assess students' understanding about the major content of ESU#1. Frequency and percentage distributions for these items were used to report the results of these survey items. Results are reported in order of the highest percentage of agreement or disagreement with the item. As shown in Table 5.8, approximately 94% (Slightly Agree: 14.9%, Agree: 16.8%, Strongly Agree: 62.4%) of Mr. Fox's students agreed that the Earth is a beautiful place (Item 1). For Item 14, approximately 75% (Slightly Agree: 31.4%, Agree: 27.5%, Strongly Agree: 16.7%) of the students agreed that they are

<table>
<thead>
<tr>
<th>Items</th>
<th>n</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Earth is a beautiful place.</td>
<td>101</td>
<td>0 (0)</td>
<td>1 (1.0)</td>
<td>5 (5.0)</td>
<td>4 (14.9)</td>
<td>5 (16.8)</td>
<td>63 (62.4)</td>
</tr>
<tr>
<td>2. One of the things that interests me the most about science are the beautiful parts of the Earth that I have encountered.</td>
<td>102</td>
<td>5 (4.9)</td>
<td>7 (6.9)</td>
<td>18 (17.6)</td>
<td>23 (22.5)</td>
<td>26 (25.5)</td>
<td>23 (22.5)</td>
</tr>
<tr>
<td>3. I appreciate the Earth more now than I did a year ago.</td>
<td>102</td>
<td>12 (11.8)</td>
<td>7 (6.9)</td>
<td>11 (10.8)</td>
<td>17 (16.7)</td>
<td>24 (23.5)</td>
<td>31 (30.4)</td>
</tr>
<tr>
<td>14. As a result of my science class, I pay more attention to the natural world around me.</td>
<td>102</td>
<td>11 (10.8)</td>
<td>10 (9.8)</td>
<td>4 (3.9)</td>
<td>32 (31.4)</td>
<td>28 (27.5)</td>
<td>17 (16.7)</td>
</tr>
</tbody>
</table>

*Note. Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA). Percentage excludes missing values.

*1 case is missing.

Table 5.8: Frequency and percentage distributions for items related to students' understanding about the major content of ESU#1.

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more interested in nature as a result of their science class. About 70% (Slightly Agree: 22.5%, Agree: 25.5%, Strongly Agree: 22.5%) of the students agreed that they are interested in aesthetic values of Earth (Item 2). Regarding students’ views on their current appreciation of the Earth, approximately 70% (Slightly Agree: 16.7%, Agree: 23.5%, Strongly Agree: 30.4%) of the students agreed with Item 3 and confirmed this appreciation.

<table>
<thead>
<tr>
<th>DV</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Value of Earth</td>
<td>7.276</td>
<td>1</td>
<td>7.276</td>
<td>6.01*</td>
<td>.015</td>
</tr>
<tr>
<td></td>
<td>222.703</td>
<td>184</td>
<td></td>
<td>1.210</td>
<td></td>
</tr>
</tbody>
</table>

*Note: p value corrected by Bonferroni’s inequality principle (Klockars & Sax, 1986). *p < .017 (95% confidence level).

Table 5.9: Result of univariate analysis of variance for self-reported knowledge mean score regarding major theme of ESU#1 between the two groups.

As can be seen in Table 5.9, the F value of the univariate analysis of variance used to compare the self-reported knowledge mean score on the major topic of ESU#1, the Value of Earth, between Mr. Fox’s students and a comparison group was significant at the 95% confidence level (F = 6.01, p < .017). Mr. Fox’s students (M = 4.87, SD = 1.11) who had ESE exhibited higher self-reported knowledge mean scores for the theme, “Value of Earth” than the comparison students (M = 4.46, SD = 1.06) who were not exposed to ESE (see Table 5.10). Interestingly, even though the comparison students were not exposed to ESE, their eighth grade science curriculum covered the topic, “the Value of the Earth” (see Appendix M). Therefore, the results
of the survey supported the researcher's expectation that Mr. Fox's students' self-reported knowledge level would be higher for this major theme of ESE#1 than that of the comparison group.

<table>
<thead>
<tr>
<th>Earth systems concepts and topics</th>
<th>Mr. Fox's students</th>
<th>Comparison students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>1. Value of Earth</td>
<td>K</td>
<td>4.87$^a$</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.79$^{b}$</td>
</tr>
<tr>
<td>2. Human activities affect Earth systems</td>
<td>K</td>
<td>5.03</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>5.29</td>
</tr>
<tr>
<td>3. Use of technology for study of science</td>
<td>K</td>
<td>4.50</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.95</td>
</tr>
<tr>
<td>4. Interaction of water, land, air, and life</td>
<td>K</td>
<td>4.52</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.89</td>
</tr>
<tr>
<td>5. Earth history</td>
<td>K</td>
<td>4.47</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.43</td>
</tr>
<tr>
<td>6. Plate tectonics processes</td>
<td>K</td>
<td>4.81</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.72</td>
</tr>
<tr>
<td>7. Structure of the solid Earth</td>
<td>K</td>
<td>4.15</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.39</td>
</tr>
<tr>
<td>8. Catastrophic events and their impacts on Earth systems</td>
<td>K</td>
<td>4.76</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.97</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.90</td>
</tr>
<tr>
<td>10. Fossil evidence</td>
<td>K</td>
<td>4.66</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.52</td>
</tr>
<tr>
<td>11. Solar system</td>
<td>K</td>
<td>4.72</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>5.06</td>
</tr>
<tr>
<td>12. Recycling of materials</td>
<td>K</td>
<td>3.79</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.06</td>
</tr>
</tbody>
</table>

Table 5.10: Summary of descriptive statistics regarding 23 Earth systems concepts and topics between the two groups.
Table 5.10 (continued)

<table>
<thead>
<tr>
<th>Earth systems concepts and topics</th>
<th>Mr. Fox’s students</th>
<th>Comparison students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>13. Changes of Earth systems through interactions of the subsystem</td>
<td>K</td>
<td>3.39</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.12</td>
</tr>
<tr>
<td>14. Cycles in nature (water cycle, rock cycle, etc.)</td>
<td>K</td>
<td>4.58</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.93</td>
</tr>
<tr>
<td>15. Motions of the planets</td>
<td>K</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.56</td>
</tr>
<tr>
<td>16. Rotation of Earth</td>
<td>K</td>
<td>4.89</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.95</td>
</tr>
<tr>
<td>17. Ecosystems</td>
<td>K</td>
<td>4.54</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.91</td>
</tr>
<tr>
<td>18. Motions of Earth and their relationships to the seasons and tidal changes</td>
<td>K</td>
<td>4.92$^a$</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>5.07$^b$</td>
</tr>
<tr>
<td>19. Careers in science</td>
<td>K</td>
<td>3.84</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.14</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.04</td>
</tr>
<tr>
<td>21. Ohio's natural resource</td>
<td>K</td>
<td>4.03</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.25</td>
</tr>
<tr>
<td>22. Ohio's geology</td>
<td>K</td>
<td>4.17</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.16</td>
</tr>
<tr>
<td>23. Environmental issues in Columbus (or Ohio)</td>
<td>K</td>
<td>4.39</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.52</td>
</tr>
</tbody>
</table>

Note. K means self-reported knowledge and S means self-perceived significance.

$^a$ Scores were measured with a 6-point scale where 1 means no knowledge and 6 means very knowledgeable.

$^b$ Scores were measured with a 6-point scale where 1 means very trivial and 6 means very significant.

$^c$ 1 case is missing.

$^d$ 1 case is missing.
Earth Systems Understanding#2 (ESU#2)

The second understanding focuses upon students’ stewardship regarding environmental issues. Frequency and percentage distributions for these items were used to report the results of the survey (Part II). Results are reported in order of the highest percentage of agreement or disagreement with the item. As presented in Table 5.11, about 86% (Slightly Agree: 20.6%, Agree: 29.4%, Strongly Agree: 36.3%) of Mr. Fox’s students agreed to some degree that they had more opportunities to learn about global environmental issues and topics, and their role in protecting the local and global environment (Item 29). For Item 15, approximately 84% (Slightly Agree: 27.5%, Agree: 29.4%, Strongly Agree: 27.5%) of the students responded that they had more opportunities to learn about their effects on the local environment. With regard to Item 11, approximately 72% (Slightly Agree: 22.8%, Agree: 32.7%, Strongly Agree: 16.8%) of the students agreed that they often noticed how human activity affects their local environment as a result of their science class. However, the results for Item 10 related to recycling of limited resources is somewhat different than expected. Approximately 57% (Slightly Agree: 26.5%, Agree: 15.7%, Strongly Agree: 15.7%) of the students agreed to some degree that they like studying about how humans manage our limited resources, reduce consumption, and recycle the resources in their local area. Students’ responses were somewhat mixed in terms of their perception related to leaning about recycling of the
limited resources and reducing consumption. Approximately 43% (Strongly Disagree: 9.8%, Disagree: 9.8%, Slightly Disagree: 22.5%) disagreed to some degree with Item 10.

<table>
<thead>
<tr>
<th>Items</th>
<th>N</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. I really like studying about how humans manage our limited resources, reduce consumption, and recycle the resources in my local area.</td>
<td>102</td>
<td>10 (9.8)</td>
<td>10 (9.8)</td>
<td>23 (22.5)</td>
<td>27 (26.5)</td>
<td>16 (15.7)</td>
<td>16 (15.7)</td>
</tr>
<tr>
<td>11. As a result of my science class, I often notice how human activity affects my local environment.</td>
<td>101</td>
<td>8 (7.9)</td>
<td>4 (4.0)</td>
<td>16 (15.8)</td>
<td>23 (22.8)</td>
<td>23 (22.7)</td>
<td>17 (16.8)</td>
</tr>
<tr>
<td>15. As a result of my science class, I am more aware of the effects that I have on the local environment.</td>
<td>102</td>
<td>3 (2.9)</td>
<td>5 (4.9)</td>
<td>8 (7.8)</td>
<td>28 (27.5)</td>
<td>30 (29.4)</td>
<td>28 (27.5)</td>
</tr>
<tr>
<td>29. As a result of my science class, I have more opportunities to learn about global environmental issues and problems, and my role in protecting the local and global environment.</td>
<td>102</td>
<td>1 (1.0)</td>
<td>5 (4.9)</td>
<td>8 (7.8)</td>
<td>21 (20.6)</td>
<td>30 (29.4)</td>
<td>37 (36.3)</td>
</tr>
</tbody>
</table>

Note. Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA). Percentage excludes missing values.

Table 5.11: Frequency and percentage distributions for items related to students’ understanding about the major content of ESU#2.

Additional evidence supporting students’ responses above can be found in my field notes and document analysis. My field notes include several reflections about Mr. Fox’s instructional focus related to ESU#2. One reflection was:

After observation: Today, Mr. Fox talked about greenhouse gases and effect. He used one activity from "Activities for the Changing Earth System." He already prepared all the equipment.
and materials for the experiment. Students got started on the experiment as a group. Most students were very actively involved in the experiment. Also, I found this activity more focused on ESUs #2, #3, and #4. But, I felt that the teacher was trying to have more attention to ESU#2. After this class, he said to me, one of the major goals to teach this issue is to help them to know about environmental problems and to enable them to make good decisions for our future. Honestly, while I observed this experiment, I also got a good chance to look at the activity regarding the parts of the greenhouse effect and the effect of CO₂. (Field Note, February 19, 2001)

I also found questions about students’ activities and tests in the unit on “Greenhouse Effect/Global Warming” strongly related to the ideas of ESU#2.

Mauna Loa CO₂ Test. (January 25, 2001)

5. What can humans do to reduce the amount of CO₂ in the Earth’s atmosphere? Why is it important to do so?

Carbon Dioxide in the Atmosphere Activity. (January 29, 2001)

6. What do you think are the differences in how people live in countries that produce little carbon dioxide compared with countries that produce a lot of carbon dioxide?

H. In what ways do you think the people who produce a lot of carbon dioxide can reduce the amount they add to the atmosphere?

Greenhouse Effect/Global Warming Test. (February 28, 2001)

7. Describe how global warming could affect Ohio and the people living here over the next 100 years.

In addition, topics and units in the eighth grade science curriculum covered many local and global environmental issues and problems (see Table 4.2). Therefore, it seems that students have multiple opportunities to learn about issues in the
classroom and on field trips. In Part 1-3 of the survey, Mr. Fox's students reported that the major theme of ESU#2, “Human activities affect Earth systems” was the one for which they were most knowledgeable ($M = 5.03$, $SD = .98$) and that they felt was most significant ($M = 5.29$, $SD = 1.00$) compared to the other themes and topics of ESUs (see Table 5.10).

As presented in Table 5.12, the results of the univariate test of mean differences revealed that Mr. Fox's students do not significantly differ in their mean score for their self-reported knowledge about the major theme of ESU#2 as compared to the comparison group. Even though the comparison students did not study these topics and themes about human influence on the Earth system (see Appendix M), the comparison students reported themselves knowledgeable ($M = 4.68$, $SD = .98$) and felt this topic was significant ($M = 5.01$, $SD = .92$).

<table>
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<tbody>
<tr>
<td>2. Human activities affect Earth systems</td>
<td>4.928</td>
<td>1</td>
<td>4.928</td>
<td>4.99</td>
<td>.027</td>
</tr>
<tr>
<td></td>
<td>181.551</td>
<td>184</td>
<td>.987</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Recycling of materials</td>
<td>13.698</td>
<td>1</td>
<td>13.698</td>
<td>7.98*</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td>315.764</td>
<td>184</td>
<td>1.716</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. $p$ value corrected by Bonferroni's inequality principle (Klockars & Sax, 1986). $p < .017$ (95% confidence level).*

Table 5.12: Results of univariate analysis of variance for self-reported knowledge mean score regarding major theme of ESU#2 between the two groups.

With regard to student responses on Item 12, the results of the univariate analysis indicated that the concept, “Recycling of materials” was significant at the
95% confidence level ($F = 7.98, p < .017$). The mean score of recycling of materials for the comparison students ($M = 4.32, SD = 1.11$) was higher than the mean score for Mr. Fox's students ($M = 3.79, SD = 1.44$). Among 23 concepts and topics, Mr. Fox's students perceived that they were least knowledgeable about the topic of "recycling of materials" (see Table 5.10). In addition, Item 12 (Part I-3 of the survey), "recycling of materials," is related to Item 10 (Part III of the survey) "...how humans manage our limited resources, reduce consumption, and recycle the resources in my local area." Only about 57% of the students agreed to some degree that they like studying about how humans manage our limited resources, reduce consumption, and recycle the resources in their local area (see Table 5.11).

In order to determine any possible reasons why Mr. Fox's students have lower self-reported knowledge scores about the topic of recycling, I examined the Lincoln Middle School's science curriculum and syllabi. The seventh grade science curriculum covered natural resources, including energy and their characteristics. All seventh graders had a chance to visit the county landfill, a wastewater treatment facility, and a compost plant. Students gained experience regarding humans' management of solid and liquid wastes. The eighth grade science curriculum dealt with these topics at a local level. Mr. Fox was teaching about Ohio natural resources with Ohio's geology. I found that the major content in the unit on Ohio's natural resources did not cover the reuse and recycling of resources very thoroughly. It seemed that eighth graders at Lincoln Middle School would not have much
opportunity to learn about recycling limited resources. In contrast, when I examined the curriculum for the comparison middle school, program objective IV-C-18 in the course Fundamentals of Science was that “Students investigate the renewable and nonrenewable nature of the earth’s resources, and explore various strategies for managing the resources” (see Appendix N).

Furthermore, the comparison school students had been involved in the Ohio Energy Project (OEP) that provided energy and conservation education for students and teachers (Ohio Energy Project, 2002). The OEP in the comparison school could be one possible explanation for the higher self-reported knowledge mean score for the comparison students compared to the unexpected relatively low self-reported knowledge mean score for “recycling of materials” for the students in Mr. Fox’s class.

*Earth Systems Understanding#3 (ESU#3)*

The third Earth Systems Understanding emphasizes a variety of scientific methods and technology to study and solve problems related to Earth systems. As presented in Table 5.13, the univariate analysis revealed that the mean score ($M = 4.50, SD = 1.12$) of Mr. Fox’s students for self-reported knowledge about the major theme of ESU#3 does not differ from that of the comparison group ($M = 4.50, SD = 1.13$). (See Table 5.10.)
<table>
<thead>
<tr>
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<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Use of technology for</td>
<td>0.000897</td>
<td>1</td>
<td>0.000897</td>
<td>.00</td>
<td>.993</td>
</tr>
<tr>
<td>study of science</td>
<td>240.452</td>
<td>184</td>
<td>1.307</td>
<td></td>
<td></td>
</tr>
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*Note. p value corrected by Bonferroni's inequality principle (Klockars & Sax, 1986).*

Table 5.13: Result of univariate analysis of variance for self-reported knowledge mean score regarding major theme of ESU#3 between the two groups.

Frequency and percentage distributions for related items in the survey (Part III) are shown in Table 5.14. Results are reported in order of the highest percentage of agreement or disagreement with the item. Most of Mr. Fox's students, about 92% (Slightly Agree: 17.6%, Agree: 34.3%, Strongly Agree: 40.2%) agreed that "When we learn science, it is important to find connections between the science disciplines" (Item 32). Approximately 75% (Slightly Agree: 21.6%, Agree: 23.5%, Strongly Agree: 30.4%) of the students agreed with Item 4, "It is difficult studying the Earth without knowing some biology, chemistry, or physics." For Item 9, approximately 72% (Slightly Agree: 17.6%, Agree: 27.5%, Strongly Agree: 27.5%) of the students agreed that they used information from more than one area of science when they tried to solve a problem in science class. Regarding Item 17, approximately 63% (Slightly Agree: 12.7%, Agree: 27.5%, Strongly Agree: 23.5%) of the students agreed to some degree that "Using technology and a variety of scientific methods are very valuable parts of learning about Earth systems." However, responses to Item 16 indicated that about 53% (Strongly Disagree: 26.5%, Disagree: 15.7%, Slightly
Disagree: 13.7%) of the students disagreed that using technology and a variety of scientific methods were very valuable parts of learning about Earth systems.

The students' responses to Items 4 and 32 indicated that Mr. Fox's students seemed to be aware of the importance of finding connections between the science disciplines in science classes. Student responses reflected the major theme of ESE#3 that ESE uses an interdisciplinary approach to integrated science. Throughout my observations of the field trips, it was noticed that most activities involved connections with other sciences or social sciences. For instance, while Mr. Fox's students were trying to test water quality by using water insects at Battelle-Darby Metro Park, they learned about human influence on water quality, various types of water insects that indicate water quality, and other chemical and physical concepts (e.g., pH, dissolved oxygen, nitrates, phosphates, hardness, water temperature, and air temperature). Thus, it seems that the students were exposed to the idea of studying Earth systems connected by all of the science disciplines. Furthermore, it was also noticed during the study that the IESS curriculum and Mr. Fox's teaching generally focus on the use of technology, including scientific technology. However, the univariate results related to the topic, "Use of technology for study of science," indicated that there was no significant difference between the two groups of students. It appears that both students have similar self-reported knowledge level related to the use of technology.
Table 5.14: Frequency and percentage distributions for items to students’ understanding about the major content of ESU#3.

Earth Systems Understanding#4 (ESU#4)

This understanding focuses on the interaction and the relationship between Earth systems and subsystems, and subsystem functions within Earth systems. Items 5, 7, 28, 30, and 31 (Survey, Part II) are designed to assess students’ understandings about the major content of ESU#4. Frequency and percentage distributions for these items were used to report the results of the survey. Results are reported in order of
the highest percentage of agreement or disagreement with the item. As shown in
Table 5.15, approximately 82% (Slightly Agree: 32.7%, Agree: 29.7%, Strongly
Agree: 19.8%) of Mr. Fox’s students agreed that environmental change usually
occurred as a result of human interactions with Earth systems (Item 28). For Item 30,
about 79% (Slightly Agree: 26.5%, Agree: 33.3%, Strongly Agree: 19.6%) of the
students agreed that it was easier to see the ways in which water, air, land and life
interact as a result of their science class. With regard to Item 5, about 75% (Slightly

<table>
<thead>
<tr>
<th>Items</th>
<th>n</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>S-D (%)</th>
<th>S-A (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. It is difficult understanding the Earth without knowing the</td>
<td>102</td>
<td>2 (2.0)</td>
<td>9 (8.8)</td>
<td>14 (13.7)</td>
<td>24 (23.5)</td>
<td>27 (26.5)</td>
<td>26 (25.5)</td>
</tr>
<tr>
<td>interacting subsystems of water, rock, ice, air, and life.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I like studying about the Earth and the other parts of Earth (its</td>
<td>102</td>
<td>6 (5.9)</td>
<td>12 (11.8)</td>
<td>22 (21.6)</td>
<td>29 (28.4)</td>
<td>17 (16.7)</td>
<td>16 (15.7)</td>
</tr>
<tr>
<td>subsystems) at the same time.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. Environmental change usually occurs as a result of human</td>
<td>101*</td>
<td>2 (2.0)</td>
<td>4 (4.0)</td>
<td>12 (11.9)</td>
<td>33 (32.7)</td>
<td>30 (29.7)</td>
<td>20 (19.8)</td>
</tr>
<tr>
<td>interactions with Earth systems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. As a result of my science class, it is easier to see the ways</td>
<td>102</td>
<td>3 (2.9)</td>
<td>6 (5.9)</td>
<td>12 (11.8)</td>
<td>27 (26.5)</td>
<td>34 (33.3)</td>
<td>20 (19.6)</td>
</tr>
<tr>
<td>in which water, air, land and life interact.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. As a result of my science class, I often recognize that the</td>
<td>102</td>
<td>7 (6.9)</td>
<td>7 (6.9)</td>
<td>19 (18.6)</td>
<td>30 (29.4)</td>
<td>21 (20.6)</td>
<td>18 (17.6)</td>
</tr>
<tr>
<td>Earth subsystems are continually changing through natural cycles and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>processes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Note. Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA). Percentage excludes missing values.
*1 case is missing.

Table 5.15: Frequency and percentage distributions for items to students' understanding about the major content of ESU#4.
Agree: 23.5%, Agree: 26.5%, Strongly Agree: 25.5 %) of the students agreed with the importance of knowing the interacting subsystems of water, rock, ice, air, and life to understand Earth. Regarding Item 31, approximately 67% (Slightly Agree: 29.4%, Agree: 20.6%, Strongly Agree: 17.6%) of the students agreed that they often recognized that the Earth subsystems were continually changing through natural cycles and processes as a result of their science class. For Item 7, approximately 60% (Slightly Agree: 28.4%, Agree: 16.7%, Strongly Agree: 15.7%) of the students agreed to some degree that “I like studying about the Earth and the other parts of Earth (its subsystems) at the same time.”

In Part I-3 of the survey, students were asked to self-report their knowledge levels about five major concepts of ESU#4 (i.e., Interaction of water, land, air, and life; Plate tectonics processes; Structure of the solid Earth; Catastrophic events and their impacts on Earth systems; Changes of Earth systems through interactions of subsystems). Mr. Fox’s students thought themselves knowledgeable about Item 6 ($M = 4.81, SD = 1.05$) and Item 8 ($M = 4.76, SD = 1.14$). The comparison group perceived a similar knowledge level for these two items ($M = 4.70, SD = 1.01$; $M = 4.77, SD = 1.17$, respectively). (See Table 5.10.) Interestingly, both groups of students seemed to be least knowledgeable about “Change of Earth systems through interactions of subsystems” (Item 13, $M = 3.39, SD = 1.50$ for Mr. Fox’s students and $M = 3.19, SD = 1.11$ for the comparison students).
When $F$ values of univariate analysis were used to determine the differences in the self-reported knowledge mean scores about five concepts, only one dependent variable (Item 4) had a significant difference ($F = 6.13, p < .017$) between Mr. Fox’s students ($M = 4.52, SD = 1.26$) and the comparison students ($M = 4.07, SD = 1.18$). (See Table 5.16.) As presented in Tables 3.1 and 4.2, Mr. Fox’s curriculum covered related concepts to ESU#4. In comparison, the eighth grade science curriculum for the comparison students focused on Earth and space science (see Appendix M). Many concepts and topics related to ESU#4 were also covered in the comparison science classes. Therefore, it appears that both students have similar self-reported knowledge levels for four concepts and topics related to ESU#4 (i.e., Items 6, 7, 8, and 13).

<table>
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<td>277.405</td>
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<td>6. Plate tectonics processes</td>
<td>.624</td>
<td>1</td>
<td>.624</td>
<td>.59</td>
<td>.444</td>
</tr>
<tr>
<td></td>
<td>195.338</td>
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<td>7. Structure of the solid Earth</td>
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<td>1</td>
<td>0.006736</td>
<td>.00</td>
<td>.955</td>
</tr>
<tr>
<td></td>
<td>380.359</td>
<td>184</td>
<td>2.067</td>
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<td></td>
</tr>
<tr>
<td>8. Catastrophic events and their impacts on Earth systems</td>
<td>0.000202</td>
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<td>0.000202</td>
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<td>.990</td>
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<td></td>
<td>248.516</td>
<td>184</td>
<td>1.351</td>
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<td>13. Changes of Earth systems through interactions of subsystems</td>
<td>1.888</td>
<td>1</td>
<td>1.888</td>
<td>1.08</td>
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<td></td>
<td>322.010</td>
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Note. $p$ value corrected by Bonferroni’s inequality principle (Klockars & Sax, 1986). *$p < .017$ (95% confidence level).

Table 5.16: Results of univariate analysis of variance for self-reported knowledge of five concepts’ mean scores regarding ESU#4 between the two groups.
According to the result of the univariate analysis related to Item 4, Mr. Fox’s students who had ESE had a significantly higher self-report knowledge mean score for the concept, “Interaction of water, land, air, and life” compared to the comparison students who were not exposed to ESE. As presented in Table 5.15, approximately 75% of Mr. Fox’s students expressed the importance of knowing the interacting subsystems of water, rock, ice, air, and life to understand Earth. In addition, this significant univariate result for Item 4 is supported by the fact that Mr. Fox’s teaching and instructional materials focused on the interaction and relationship between Earth systems and subsystems.

**Earth Systems Understanding#5 (ESU#5)**

The fifth understanding focuses on the great age of the Earth and the constant evolution of subsystems through time. ESU#5 is primarily composed of four important concepts and topics: cycles in nature (e.g., water cycle, rock cycle); Earth history; evolution; and fossil evidence. As can be seen in Table 5.10, both the students in Mr. Fox’s class and the comparison class reported knowledge mean scores on the following two concepts of ESU#5 as slightly higher than those for other concepts: evolution ($M = 4.80, SD = 1.17; M = 4.90, SD = 1.14$, respectively), and fossil evidence ($M = 4.66, SD = 1.12; M = 4.73, SD = 1.11$, respectively).

The univariate analysis was utilized to determine if a statistically significant difference between the two groups existed at $\alpha < .017$ for self-reported knowledge.
mean scores for the 4 concepts and topics related to ESU#5 (see Table 5.17). Only one concept related to ESU#5, "Cycles in nature", was significant \( (F = 6.67, p < .017) \). The mean for self-reported knowledge about "Cycles in nature" (Item 14, Part I-3) for Mr. Fox’s students \( (M = 4.58, SD = 1.25) \) was significantly higher than the mean for the comparison students \( (M = 4.16, SD = 1.13) \). In order to determine any possible reason why Mr. Fox’s students had a higher self-reported knowledge mean score related to this topic, I examined the school science curriculum. Seventh graders studied concepts related to cycles in nature, such as rock cycle, carbon cycle, water cycle, and nitrogen cycle. Though the eighth grade science curriculum doesn’t deal with these concepts, students seem to remember them. In addition, the results could be explained by the fact that the comparison students did not study concepts or topics associated with cycles in nature (see Appendix M).

<table>
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<tr>
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<th>MS</th>
<th>F</th>
<th>p</th>
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<tr>
<td>5. Earth History</td>
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<td>.07</td>
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<td></td>
<td>276.410</td>
<td>184</td>
<td>1.502</td>
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<td></td>
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<td>9. Evolution</td>
<td>.521</td>
<td>1</td>
<td>.521</td>
<td>.38</td>
<td>.538</td>
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<td>252.559</td>
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<td>10. Fossil Evidence</td>
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<td>.290</td>
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<td>264.691</td>
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</table>

Note. \( p \) value corrected by Bonferroni’s inequality principle (Klockars & Sax, 1986). \(*p < .017 \) (95% confidence level).

Table 5.17: Results of univariate analysis of variance for self-reported knowledge of four concepts’ mean scores regarding ESU#5 between the two groups.
Earth Systems Understanding#6 (ESU#6)

The sixth understanding focuses on the solar system and the fact that Earth is a small subsystem within the vast and ancient universe. The main concepts and topics regarding ESU#6 include solar system, motions of the planets, rotation of Earth, and motions of Earth and their relationships to the seasons and tidal changes. As presented in Table 5.10, most mean scores, perceived by Mr. Fox’s students and the comparison students, were reported to be relatively high: solar system ($M = 4.72, SD = 1.27$; $M = 4.76, SD = 1.25$, respectively), motions of the planets ($M = 4.28, SD = 1.34$; $M = 4.35, SD = 1.36$, respectively), rotation of Earth ($M = 4.89, SD = 1.15$; $M = 4.95, SD = 1.12$, respectively), and motions of Earth and their relationships to the seasons and tidal changes ($M = 4.92, SD = 1.01$; $M = 4.93, SD = 1.04$, respectively). Interestingly, all mean scores for self-reported knowledge level for the comparison group were slightly higher than the mean scores for Mr. Fox’s students. However, none of the pairs of means differ significantly between the two groups of students (see Table 5.18).

These results could be explained by the fact that both groups of students had opportunities to study these concepts and topics related to ESU#6. The four main concepts and topics were covered when Mr. Fox taught the weather unit. Most concepts and topics (e.g., solar system, Earth, and moon) had already been covered in the science classes of the comparison group (see Appendix M).
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<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
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<tr>
<td>11. Solar system</td>
<td>.08342</td>
<td>1</td>
<td>.08342</td>
<td>.05</td>
<td>.822</td>
</tr>
<tr>
<td></td>
<td>301.529</td>
<td>184</td>
<td>1.639</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Motions of the planets</td>
<td>.209</td>
<td>1</td>
<td>.209</td>
<td>.11</td>
<td>.736</td>
</tr>
<tr>
<td></td>
<td>339.253</td>
<td>184</td>
<td>1.844</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Rotation of Earth</td>
<td>.142</td>
<td>1</td>
<td>.142</td>
<td>.11</td>
<td>.742</td>
</tr>
<tr>
<td></td>
<td>241.707</td>
<td>184</td>
<td>1.314</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Motions of Earth and their relationships to the seasons and tidal changes</td>
<td>.000678</td>
<td>1</td>
<td>.000678</td>
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<td>.980</td>
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<tr>
<td></td>
<td>195.790</td>
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<td>1.064</td>
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*Note. p value corrected by Bonferroni's inequality principle (Klockars & Sax, 1986).*

Table 5.18: Results of univariate analysis of variance for self-reported knowledge of four concepts' mean scores regarding ESU#6 between the two groups.

**Earth Systems Understanding#7 (ESU#7)**

The last understanding deals with careers and avocations in sciences that study Earth. Items 8, 20, and 21 (Survey, Part II) are designed to assess students' understandings about the major content of ESU#7. Frequency and percentage distributions for these items were used to report the results of the survey. Results are reported in order of the highest percentage of agreement or disagreement with the item. As shown in Table 5.19, approximately 86% (Slightly Agree: 14.7%, Agree: 28.4%, Strongly Agree: 43.1%) of Mr. Fox's students agreed that they had more opportunities to learn careers involving Earth systems science that were open to them (Item 21). For Item 20, approximately 81% (Slightly Agree: 32.4%, Agree: 32.4%, Strongly Agree: 16.7%) of the students agreed that scientists from many different
countries should collaborate to study the Earth’s origin, processes, and evolution.

With regard to Item 8, approximately 73% (Slightly Agree: 24.5%, Agree: 34.3%, Strongly Agree: 14.7%) of the students agreed that “Combining information from all of the scientists and technicians makes solving problems about the Earth easier.” It seems that student had opportunities to learn about careers related to Earth systems science and were exposed to them throughout the school year.

<table>
<thead>
<tr>
<th>Items</th>
<th>8. Combining information from all of the scientists and technicians makes solving problems about the Earth easier.</th>
<th>20. As a result of my science class, I think that scientists from many different countries should collaborate to study the Earth’s origin, processes, and evolution.</th>
<th>21. As a result of my science class, I am more aware that there are many careers involving Earth systems science that are open to girls and boys.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Items</td>
<td>n</td>
<td>SD (%)</td>
<td>D (%)</td>
</tr>
<tr>
<td>8. Combining information from all of the scientists and technicians makes solving problems about the Earth easier.</td>
<td>102</td>
<td>5 (4.9)</td>
<td>9 (8.8)</td>
</tr>
<tr>
<td>20. As a result of my science class, I think that scientists from many different countries should collaborate to study the Earth’s origin, processes, and evolution.</td>
<td>102</td>
<td>1 (1.0)</td>
<td>8 (7.8)</td>
</tr>
<tr>
<td>21. As a result of my science class, I am more aware that there are many careers involving Earth systems science that are open to girls and boys.</td>
<td>102</td>
<td>0 (0)</td>
<td>2 (2.0)</td>
</tr>
</tbody>
</table>

*Note. Students respond on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Slightly Disagree (S-D), 4 = Slightly Agree (S-A), 5 = Agree (A), and 6 = Strongly Agree (SA). Percentage excludes missing values. *1 case is missing.

Table 5.19: Frequency and percentage distributions for items to students’ understanding about the major content of ESU#7.

As presented in Table 5.20, the univariate analysis revealed that there was no significant difference between the mean score for Mr. Fox’s students.
\(M = 3.84, SD = 1.32\) compared to the mean score for the comparison group \(M = 3.87, SD = 1.34\) with respect to self-reported knowledge for the major concept in ESU\#7 “Careers in science” (Item 19, Part II of the survey.) (See Table 5.10.)

Because the participants in the study were middle school students, I assume that these students may have some knowledge and information about careers related to Earth and Earth systems. When I examined the curriculum of Lincoln Middle School, the seventh graders had an opportunity to learn about branches of science, such as Biochemistry, Paleontology, Entomology, Zoology, and Bacteriology. In addition, students could learn about careers in Earth systems through their mini-projects and group projects. For example, when they studied El Niño as group projects, one research question was “How do scientists study El Niño?” They studied different types of roles and responsibilities of scientists and technicians who work on the El Niño phenomenon. Mr. Fox also introduced some careers in sciences when students were doing experiments in the laboratory and doing their projects.

For the comparison students, the eighth graders had several opportunities to learn about careers related to Earth and space science (e.g., Seismologist, Volcanologist, Geophysicist, Gem Cutter, Soil Scientist, Biological Oceanographer, Cartographer, Geologist, Astronomer, and Aerospace Engineer). Their textbook included explanations and descriptions about these scientists. Therefore, the results of the univariate analysis regarding careers in science could be explained by the fact that both groups of students studied this content.
Note. P value corrected by Bonferroni's inequality principle (Klockars & Sax, 1986).

Table 5.20: Result of univariate analysis of variance for self-reported knowledge mean score regarding major concept of ESU#7 between the two groups.

**Students' Self-Reported Knowledge Level of Local Topics**

In addition to exploring students' perceptions of concepts and themes associated with the Framework of Seven Earth Systems Understandings, students' self-reported knowledge levels of an additional five local topics identified in Mr. Fox's syllabus were examined: ecosystems (local community), urban watersheds, Ohio's natural resources, Ohio's geology, and environmental issues in Columbus (or Ohio). Based on the focus of the IESS curriculum, it seemed that Mr. Fox's students could have many opportunities to deal with local topics and issues.

As presented in Table 5.10, two mean scores (Survey Part I-3, Items 17 and 20) for self-reported knowledge for the comparison group ($M = 4.61, SD = 1.02$; $M = 4.23, SD = 1.40$, respectively) were slightly higher than the mean scores for Mr. Fox's students ($M = 4.54, SD = 1.05$; $M = 4.19, SD = 1.37$, respectively). However, these mean scores do not differ significantly between the two groups of students (see Table 5.21). The mean scores of Mr. Fox's students for Item 21 ($M = 4.03, SD = 1.47$), Item 22 ($M = 4.17, SD = 1.37$), and Item 23 ($M = 4.39, SD = 1.26$) were
slightly higher than that of the comparison students ($M = 3.88, SD = 1.41; M = 3.94, SD = 1.21; M = 3.91, SD = 1.29$, respectively). However, only one mean score, Item 23 “Environmental issues in Columbus (or Ohio)” was significantly higher for Mr. Fox’s students ($F = 5.99, p < .017$) compared to the comparison group. Other pairs of means did not differ significantly between the two groups of students.

<table>
<thead>
<tr>
<th></th>
<th>DV</th>
<th>$SS$</th>
<th>$df$</th>
<th>$MS$</th>
<th>$F$</th>
<th>$p$</th>
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<td>17</td>
<td>Ecosystems</td>
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<td>1</td>
<td>.226</td>
<td>.20</td>
<td>.654</td>
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<td></td>
<td></td>
<td>205.624</td>
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<td>1.118</td>
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<td>20</td>
<td>Urban Watersheds</td>
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<td>1</td>
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<td>.812</td>
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<td></td>
<td></td>
<td>369.526</td>
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<td>2.008</td>
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<tr>
<td>21</td>
<td>Ohio’s natural resource</td>
<td>.844</td>
<td>1</td>
<td>.844</td>
<td>.40</td>
<td>.528</td>
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<tr>
<td></td>
<td></td>
<td>388.382</td>
<td>184</td>
<td>2.111</td>
<td></td>
<td></td>
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<tr>
<td>22</td>
<td>Ohio’s geology</td>
<td>1.883</td>
<td>1</td>
<td>1.883</td>
<td>1.11</td>
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<td></td>
<td></td>
<td>312.853</td>
<td>184</td>
<td>1.700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Environmental issues in Columbus (or Ohio)</td>
<td>9.905</td>
<td>1</td>
<td>9.905</td>
<td>5.99*</td>
<td>.015</td>
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<tr>
<td></td>
<td></td>
<td>304.461</td>
<td>184</td>
<td>1.655</td>
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</table>

*Note. $p$ value corrected by Bonferroni’s inequality principle (Klockars & Sax, 1986). $*p < .017$ (95% confidence level).

Table 5.21: Results of univariate analysis of variance for self-reported knowledge of local topics’ mean scores between the two groups.

From the evidence presented in Chapter 4, the focus of IESS for Mr. Fox’s eighth graders begins with local issues and topics around their community and Ohio.
and extends to global issues. Most topics and units in the eighth grade science curriculum covered many local and global environmental issues and problems (see Table 4.2). In contrast, the major units and topics for the comparison students did not include much opportunity to learn about local environmental issues. These facts could explain the result of the univariate analysis regarding local topics in favor of Mr. Fox's students.

**Students' Self-Reported Knowledge and Self-Perceived Significance Levels**

This subsection relates to Research question 6: How do IESS students’ self-reported knowledge and perceived significance levels, and their primary information sources about Earth systems and environmental topics differ from those of a comparison group? Findings associated with students’ self-reported knowledge, self-perceived significance levels, and primary information source on 13 Earth systems and environmental topics are presented. The univariate tests (ANOVAs) were used to identify significant differences between Mr. Fox’s students and the comparison students for each knowledge and significance level mean score for the 13 Earth systems and environmental topics (dependent variables). Frequencies and percentages were used to report the primary information sources for the two student groups.

In Part I-1 of the survey, items assess the degree of a student’s self-reported knowledge and the perceived significance associated with 13 selected Earth systems
and environmental topics. The self-reported knowledge and perceived-significance levels for the environmental topics were compared between Mr. Fox's students and the comparison group.

In relation to students' self-reported knowledge level, Mr. Fox's students reported themselves to be most knowledgeable about the ozone hole ($M = 5.10, SD = 1.02$), global warming ($M = 4.84, SD = 1.02$), air pollution ($M = 4.74, SD = 1.04$), and El Niño ($M = 4.64, SD = .89$), whereas introduced species ($M = 3.61, SD = 1.50$) and loss of biodiversity ($M = 3.94, SD = 1.36$) were reported at a least knowledgeable level. In contrast, the comparison group reported themselves to be most knowledgeable of loss of biodiversity ($M = 5.16, SD = .97$), trash disposal ($M = 4.88, SD = 1.29$), air pollution ($M = 4.80, SD = 1.18$), and water pollution ($M = 4.71, SD = 1.26$). Pesticides in agriculture ($M = 2.57, SD = 1.43$), acid rain ($M = 2.74, SD = 1.37$), and El Niño ($M = 2.81, SD = 1.71$) were reported to be least familiar by students in the comparison group (see Table 5.22).

The $F$ values from the univariate analyses were utilized to determine if a statistically significant difference existed at $\alpha < .017$ or better (95% confidence level) for self-reported knowledge scores for each of the environmental topics (each dependent variable) between the two groups. As presented in Table 5.23, results of the univariate tests for the self-reported knowledge scores between the two groups indicated that 7 of the 13 dependent variables (environmental topics) were
<table>
<thead>
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<th>Earth systems and environmental topics</th>
<th>Mr. Fox’s students</th>
<th>Comparison students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
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<tr>
<td></td>
<td>S</td>
<td>4.23$^b$</td>
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<td>4.74</td>
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<td></td>
<td>S</td>
<td>4.91</td>
</tr>
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<td>K</td>
<td>4.19</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.24</td>
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<td></td>
<td>S</td>
<td>4.81</td>
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<td>K</td>
<td>4.84</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.65</td>
</tr>
<tr>
<td>Introduced Species</td>
<td>K</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>3.17</td>
</tr>
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<td>Loss of biodiversity</td>
<td>K</td>
<td>3.94</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.10</td>
</tr>
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<td>Oil Spills</td>
<td>K</td>
<td>4.36</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4.85</td>
</tr>
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<td>Ozone Hole</td>
<td>K</td>
<td>5.10</td>
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<td>S</td>
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<td></td>
<td>S</td>
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<td>S</td>
<td>4.10</td>
</tr>
</tbody>
</table>

**Note.** K means self-reported knowledge and S means self-perceived significance.

$^a$Scores were measured with a 6-point scale where 1 means no knowledge and 6 means very knowledgeable.

$^b$Scores were measured with a 6-point scale where 1 means very trivial and 6 means very significant.

$^c$1 case is missing.

$^d$1 case is missing.

Table 5.22: Summary of descriptive statistics of 13 Earth systems and environmental topics.

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significantly different: acid rain \((F = 96.35, p < .000)\); global warming \((F = 34.36, p < .000)\); loss of biodiversity \((F = 50.89, p < .000)\); ozone hole \((F = 91.13, p < .000)\); pesticides in agriculture \((F = 59.44, p < .000)\); soil erosion \((F = 6.62, p < .017)\); and El Niño \((F = 89.72, p < .000)\). The self-perceived knowledge score of the comparison group was statistically higher than that of for Mr. Fox’s students for only one of the seven topics, loss of biodiversity.

With regard to the self-perceived significance level for environmental issues, the scores of students’ perceived significance will be higher when they think or believe that an environmental problem is more significant, serious, certain, and more harmful to their health and well-being (Lee J., 2000). From Mr. Fox’s students’ point of view, the most significant environmental issues were ozone hole \((M = 5.06, SD = .93)\), air pollution \((M = 4.91, SD = .87)\), oil spills \((M = 4.85, SD = 1.20)\), and water pollution \((M = 4.81, SD = .95)\), whereas introduced species \((M = 3.17, SD = 1.44)\) and soil erosion \((M = 3.19, SD = 1.16)\) were reported to be least significant (see Table 5.22). For the comparison group, the most significant environmental issues were water pollution \((M = 5.04, SD = 1.02)\), air pollution \((M = 4.89, SD = 1.04)\), and acid rain \((M = 4.16, SD = 1.24)\). More trivial issues were introduced species \((M = 2.50, SD = 1.31)\) and soil erosion \((M = 2.86, SD = 1.22)\). (See Table 5.22.)
<table>
<thead>
<tr>
<th>DV</th>
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<th>df</th>
<th>MS</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
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<td>Acid Rain</td>
<td>135.664</td>
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<td>135.664</td>
<td>96.35 ***</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>270.341</td>
<td>192</td>
<td>1.408</td>
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<td></td>
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<td>1</td>
<td>.137</td>
<td>.11</td>
<td>.783</td>
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<td></td>
<td>234.425</td>
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<td>1.221</td>
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<td>Deforestation</td>
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<td>1</td>
<td>10.590</td>
<td>4.89</td>
<td>.028</td>
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<td>416.157</td>
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<td></td>
<td></td>
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<tr>
<td>Water Pollution</td>
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<td>1</td>
<td>1.022</td>
<td>.70</td>
<td>.403</td>
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<tr>
<td></td>
<td>279.993</td>
<td>192</td>
<td>1.458</td>
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<tr>
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<td>1</td>
<td>57.408</td>
<td>34.36 ***</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>320.777</td>
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<td></td>
</tr>
<tr>
<td>Introduced Species</td>
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<td>4.108</td>
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<td>.201</td>
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<td>478.263</td>
<td>192</td>
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<tr>
<td>Loss of biodiversity</td>
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<td>50.89 ***</td>
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<td>.679</td>
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<td>.000</td>
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<td>.000</td>
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<td>349.684</td>
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<td>1.821</td>
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*Note. p value corrected by Bonferroni's inequality principle (Klockars & Sax, 1986).  
*p < .017. ***p < .0033. ***p < .000.

Table 5.23: Univariate analysis of variance follow up to significant MANOVA analyses for self-reported knowledge scores of 13 Earth systems and environmental topics.
ANOVA were used to check for significance differences between the two groups in self-perceived levels for the 13 topics. As presented in Table 5.24, differences for the following five dependent variables (five environmental topics) were found to be significant ($\alpha < .017$ or better): Global warming ($F = 17.38$, $p < .000$), introduced species ($F = 10.82$, $p < .0033$), loss of biodiversity ($F = 8.43$, $p < .017$), pesticides in agriculture ($F = 7.50$, $p < .017$), and El Niño ($F = 18.14$, $p < .000$). Interestingly, Mr. Fox’s students perceived all five environmental issues to be more significant than did the comparison students. For five of the 13 topics (dependent variables), the mean scores for the perceived-significance level for Mr. Fox’s students were significantly higher than those of the comparison group.

<table>
<thead>
<tr>
<th>DV</th>
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<th>$MS$</th>
<th>$F$</th>
<th>$p$</th>
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<td>267.602</td>
<td>192</td>
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Table 5.24: Univariate analysis of variance follow up to significant MANOVA analyses for self-perceived significance scores of 13 Earth systems and environmental topics.
Table 5.24 (continued)

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<th>Topic</th>
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<th>F</th>
<th>df</th>
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<td>365.364</td>
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</tr>
<tr>
<td>Loss of biodiversity</td>
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<td>18.967</td>
<td>1</td>
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<td>13.005</td>
<td>1</td>
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<td>370.440</td>
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<td>El Niño</td>
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<td>27.594</td>
<td>1</td>
<td>18.14 ***</td>
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<tr>
<td></td>
<td>291.999</td>
<td>192</td>
<td>1.521</td>
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</table>

Note. p value corrected by Bonferroni’s inequality principle (Klockars & Sax, 1986).
* p < .017. ** p < .0033. *** p < .000.

Students' Primary Information Source on the 13 Topics

The overwhelming majority of Mr. Fox’s students responded that their most frequent information source related to Earth systems and environmental topics was their school. The percentage of Mr. Fox’s students that reported school as their primary source of information was highest for the following topics: acid rain (88.2%), loss of biodiversity (83.3%), ozone hole (77.5%), soil erosion (75.5%),

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global warming (71.6%), and water pollution (71.6%). The lowest percentage was for oil spills (37.3%) and the information source was TV (see Table 5.25).

<table>
<thead>
<tr>
<th>Earth systems &amp; Environmental Topics</th>
<th>Mr. Fox's students</th>
<th>Comparison group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Items</td>
<td>Missing Value</td>
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<tr>
<td></td>
<td>(N = 102)</td>
<td>(N = 94)</td>
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<td>Acid Rain</td>
<td>School (90)</td>
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<tr>
<td>Air Pollution</td>
<td>School (76)</td>
<td>5</td>
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<tr>
<td>Deforestation</td>
<td>School (61)</td>
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<tr>
<td>Water Pollution</td>
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<td>Introduced Species</td>
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<td>Loss of biodiversity</td>
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<td>Oil Spills</td>
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<td>Ozone Hole</td>
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<td>Pesticides in Agriculture</td>
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<td>Soil Erosion</td>
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<td>Trash Disposal</td>
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<td>4</td>
</tr>
<tr>
<td>El Niño</td>
<td>School (60)</td>
<td>6</td>
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</tbody>
</table>

*Note.* Nine information sources are provided: School (Class), Parents, TV, Internet, Newspaper, Books, Magazines, Radio, and Don’t know.

*Percentage excludes missing values.*

Table 5.25: Students’ primary information sources on 13 Earth systems and environmental topics.
The comparison students responded that their most frequent source for information on Earth systems and environmental topics was also school for the following topics: air pollution (63.8%), trash disposal (58.5%), water pollution (56.4%), soil erosion (50%), and global warming (48.9%). The percentage of students in the comparison group who reported school as their primary source of information was lower for the following topics: deforestation (41.5%), loss of biodiversity (39.4%), acid rain (35.1%), and introduced species (34%). The lowest percentage was for oil spills (29.8%) and the information source was TV and school (see Table 5.25).

Notable differences between the two groups were observed in that school (or class) was considered the primary information source for most of the 13 environmental topics for Mr. Fox's students. In particular, 59 % (n = 60) of Mr. Fox's students selected school as the primary information source, whereas the comparison students were more dependent on TV as a source (35 %, n = 33) rather than school (15 %, n = 16). Interestingly, for the oil spills topic, both Mr. Fox's students and comparison students selected TV and school as the first and second primary information sources for this topic. Other student information sources related to these topics are summarized in Appendix O.

In summary, the focus of this second section was to present, through the results of the survey, the understandings of students in relation to the Framework of Seven ESUs, and the students' self-reported knowledge and perceived significance on Earth systems concepts and environmental topics. The results of this second section will be summarized and interpreted in Chapter 6.
CHAPTER 6

SUMMARY AND IMPLICATIONS

A good science teacher is well grounded in content and pedagogy. She or he treats students as individuals and pays attention to different ways of learning and the many ways of teaching. The role of a good teacher is that of counselor, facilitator, content expert and leader. (Mr. Fox, Written Question)

In this chapter, I summarize findings related to Mr. Fox and the students in both his class and the comparison school as reported in the previous two chapters, Chapter 4 and Chapter 5. Following the summary, I discuss implications for science educators and further research.

Summary

During the last two decades, there have been many efforts and developmental projects to spread and implement a new focus and philosophy for an integrated science curriculum called Earth Systems Education (ESE; Mayer, 1991a). For example, in Ohio, ESE has been implemented at several middle and high schools since 1992. Despite such a history of efforts to spread and implement ESE, there has been no empirical research to answer questions about the implementation of Earth
Systems Education in schools. Therefore, in order to document descriptive and analytical accounts of IESS curriculum and instruction in a natural classroom, I studied the science classrooms of an information-rich teacher who had experience with implementing ESE in a middle school and who employed the ESE conceptual focus and approach in his science curriculum. I studied one teacher, Mr. Fox, who was one of the principal contributors to ESE and was one of the investigators in the Program for Leadership in Earth System Education (PLESE) project. He developed a two-year Integrated Earth Systems Science (IESS) course that was substituted for the traditional seventh grade life science and eighth grade Earth science courses at his school.

In this investigation, I conducted a case study of the IESS curriculum provided by Mr. Fox. My research questions primarily focused on the teacher's views of ESE, its theoretical background, and several characteristics of IESS curriculum and instruction. In addition, I explored the views of students in Mr. Fox's science classes related to the characteristics of IESS curriculum and instruction and their understanding of the ESE framework. I compared self-reported knowledge and self-perceived significance levels and primary information sources of eighth grade students in Mr. Fox's science classes and eighth grade students in science classes in a comparison school.

Through qualitative and quantitative data collection and analyses, I was able to obtain evidence from the teacher and students. Survey results were subjected to a multivariate analysis of variance (MANOVA) to determine differences between the
two groups in scores of students' self-reported knowledge and self-perceived significance of Earth systems concepts and environmental topics. If the MANOVA was significant at a 95% confidence level, univariate ANOVAs were conducted at the 95% confidence level ($\alpha = 0.05/3 = .017$) on the basis of Bonferroni's inequality principle. Based on the evidence, I could provide answers to the following major questions: 1. How does an ESE teacher implement the integrated science curriculum in the middle school? and 2. What are the students' views about the IESS curriculum and instruction? The summary includes Mr. Fox's views about ESE and IESS experiences, characteristics of the IESS curriculum, Mr. Fox's students' perceived understandings of the ESE framework, and the students' perceived understandings of Earth systems concepts and topics.

**Mr. Fox's Views About ESE and IESS Experiences**

Mr. Fox's views about ESE and his IESS curriculum and instruction were first examined through interviews and observations. As the evidence was analyzed, it became apparent that there are commonalities between constructivist theory and his perceptions of science education and pedagogy. He holds a constructivist-based philosophy for teaching IESS. He believes that science learning is an active process by the students, facilitated by the teacher. Students are actively constructing new knowledge based on their prior experience, including misconceptions. Therefore, he strongly believes that teachers should know their students' pre-existing knowledge, beliefs, and misconceptions. He uses several teaching strategies to
identify students' misconceptions (e.g., concept mapping, brainstorming, open-ended questions). In addition, he uses a variety of teaching strategies, all of which are compatible with ESE and constructivist theory. His major strategies include cooperative learning, inquiry, a jigsaw approach, labs, authentic activities, field trips, and project-based learning. In particular, his use of concept maps, cooperative learning, and authentic activities are primarily based on constructivist learning theory and meaningful learning (Ausubel, 1963; Novak, 1990, 1991; Piaget 1977).

Next, he believes that middle school students need more opportunities to make sense of the world around them. Therefore, he explains that his IESS curriculum and instruction focuses on making science learning relevant to student real world experiences and real life environments. Providing authentic classroom activities and field trips is also consistent with the constructivist perspective. He also provides integrated hands-on activities rather than “cookbook” labs because he wants to provide students with more opportunities to use their thinking and process skills.

With respect to his views about benefits and difficulties associated with IESS, he suggests that the most important benefit is that the IESS curriculum provides authentic-based, hands-on activities and makes connections between students and everyday life experiences. In addition, he believes that it is not difficult to teach using IESS. However, the lack of time devoted to field trips and a lack of suitable resource materials that reflect ESE are obstacles to the implementation of the IESS curriculum for some teachers.
Characteristics of the IESS Curriculum

From the evidence presented in Chapters 4 and 5, there are several notable characteristics of the IESS curriculum. First, the Integrated Earth Systems Science (IESS) curriculum, developed by Mr. Fox and other teachers in the middle school, was based on a framework of Earth Systems Education. As Mayer (1995) suggests, the Earth as a system provides conceptual focus and themes for organizing the IESS curriculum. For example, the focus of IESS for Mr. Fox’s eighth graders begins with local issues and topics around their community and Ohio and extends to global issues, such as global warming, El Niño, and ozone depletion. The topics for Mr. Fox’s curriculum were selected on the basis of the ESE framework. The instructional subject matter is primarily composed of interdisciplinary investigations, human interactions (or influence) with Earth systems, the Framework of Earth Systems Understandings, and global concepts approached on a regional basis.

With regard to students’ views on the IESS curriculum and content, Mr. Fox’s students clearly responded that they are interested in learning about science topics related to their daily lives. One reason they enjoyed and liked science learning was that they could obtain locally relevant knowledge and apply it to their everyday lives. According to the results of the survey, Mr. Fox’s students agreed that what they have learned from science class is important to their real everyday lives and would help them make good decisions in the future.

Second, evidence was obtained during the study that emphasized the importance of hands-on activities. Since hands-on learning is supported by Dewey...
(1916, 1938) as a vital part of the education of all students, the concept of teaching through hands-on learning methods has continued to be an important part of science education (Folkomer, 1981, LaPorte & Sanders, 1993; Orion & Hofstein, 1994; Tal, 2001; Thomson & Hartog, 1993; Wolfinger, 1994). Mr. Fox’s students responded that hands-on based experiences and activities during the field trips helped them to understand the local environment and nature. Students perceived themselves better able to understand the concepts presented in the lessons by hands-on learning.

Third, the evidence presented in the previous two chapters illustrates that field trips play an important role in IESS, fostering greater understanding of the local environment and human influences on it. The IESS curriculum included several valuable field trips for both seventh and eighth graders. The major focus of the field trips was examining and experiencing the local environment, human influences on the environment, and science knowledge and concepts. In addition, evidence from the students indicates that they were able to better understand the concepts through the field trip experiences. It seems particularly significant that many of the students mentioned the field trips as most interesting and enjoyable learning activities. According to the survey, the students responded positively to the field trips as a part of their IESS curriculum, and showed interest in learning during the field trips.

The final notable characteristic of the IESS curriculum is the inclusion of mini-projects organized by Mr. Fox. Twice a year, the students study any science topic of their choice and develop an oral presentation (mini-project) on a topic. The responses of students to their mini-projects indicated that they had an opportunity to
study new and interesting science topics in depth and to learn about science process skills (e.g., observing, inferring, and organizing and interpreting data) and other skills (e.g., presentation skills, information searching skills on the Internet). The mini-projects also helped students to understand additional Earth system and science concepts. On the oral presentation day, students could share their topics with other students. The teacher videotaped and assessed presentations using a teacher-made evaluation form and provided productive feedback and comments.

**Students' Perceived Understandings of the ESE Framework**

In this subsection, I summarize and interpret the findings regarding Mr. Fox's students' understanding of the ESE Framework and significant results of the univariate analyses comparing Mr. Fox's students to students in a comparison group. The first Earth Systems Understanding (ESU) is considered a starting point for engaging all students in studies of the Earth and the real world around them. As mentioned in the review of literature, in ESE, students have an opportunity to develop an appreciation of Earth and a sense of stewardship for the Earth. According to the evidence provided in Chapter 4, Mr. Fox's IESS classes and field trips, such as Battelle-Darby Metro Park and Pickerington Ponds Metro Park, provided an opportunity for students to learn about the Earth through aesthetic experiences and understand the aesthetic qualities and develop an appreciation of the Earth. In the survey, Mr. Fox's students' responses reflected the underlying themes of the first Earth Systems Understanding. In particular, Mr. Fox's students have a significantly
higher self-reported knowledge mean score for ESU#1, “Value of Earth” compared to the comparison students. Therefore, the results of the survey indicate that Mr. Fox’s students’ self-reported knowledge level is higher than that of the comparison group for the major theme of ESU#1.

Second, the major focus of ESU#2 is to foster and develop students’ stewardship regarding environmental issues. The major units and topics in Mr. Fox’s eighth grade science classes cover local and global environmental topics as well as human interactions and influences on environmental issues. In the survey, a majority of Mr. Fox’s students agreed that they had more opportunities to learn about global environmental issues and topics, human effects on the local environment, and their role in protecting the local and global environment. In addition, Mr. Fox’s students reported that the major theme of ESU#2, “Human activities affect Earth systems” was the one for which they were most knowledgeable and that they felt was most significant compared to the other themes and topics of the ESUs. However, the results of the univariate test revealed that Mr. Fox’s students do not significantly differ in their mean score for their self-reported knowledge about this theme as compared to the comparison group. Even though the comparison students did not study these topics and themes about the human influence on the Earth system, the comparison students reported themselves knowledgeable about “Human activities affect Earth systems” and felt that this topic was significant.

Third, ESU#3 focuses on a variety of scientific methods and technology to study and solve problems related to Earth systems. Throughout the study, Mr. Fox
provided opportunities to engage students in using technology and scientific methods to promote the understanding that Earth systems are interrelated and connected with all sciences. For example, the mini-projects included a major focus on use of technology and process skills of science. Mr. Fox's students used the Internet and other technologies to study and collect data and report experiences and their results, as described in Chapter 5. Additionally, the results of the survey (Part III) indicate that Mr. Fox's students believe that the use of different scientific methods and technology is important to understand and study Earth systems, and recognize that all of the science disciplines are interconnected through the Earth's systems. However, the univariate results related to the topic, "Use of technology for study of science," indicated that there was no significant difference between the two groups of students. It appears that both students have similar self-reported knowledge level related to the use of technology.

Fourth, ESU#4 focuses on the interaction and the relationship between Earth system and subsystems, and subsystem functions within Earth systems. In the survey, Mr. Fox's students who had ESE had a significantly higher self-report knowledge mean score for the concept, "Interaction of water, land, air, and life" compared to the comparison students who were not exposed to ESE. Approximately 75% of Mr. Fox's students expressed the importance of knowing the interacting subsystems of water, rock, ice, air, and life to understand Earth. This result is supported by the fact that Mr. Fox's teaching and instructional materials focus on the interaction and relationship between Earth system and subsystems. Furthermore,
evidence from the characteristics of the field trips supports the findings related to ESU#4. The field trips provided wonderful opportunities for firsthand observations of Earth systems and hands-on experiences and activities related to its subsystems.

Fifth, ESU#5 emphasizes Earth history and the constant evolution of subsystems through time. Self-reported knowledge level mean scores for Mr. Fox’s students were slightly lower than the mean scores for the comparison students for three concepts and topics of ESU#5: earth history, evolution, and fossil evidence. However, none of the pairs of means differ significantly between the two groups of students. In addition, the mean score for self-reported knowledge level for another concept related to ESU#5, “Cycles in nature”, was significantly higher for Mr. Fox’s students compared to the comparison students. When I examined the science curriculum, I found that the seventh grade science curriculum at Lincoln Middle School deals with the topic of cycles in nature (e.g., rock cycle, carbon cycle, water cycle, and nitrogen cycle). However, Mr. Fox doesn’t deal with these topics in the eighth grade science classes. The comparison students also did not study concepts or topics associated with cycles in nature. There does not appear to be an explanation for the significantly higher self-reported knowledge level for cycles in nature by Mr. Fox’s students. Perhaps these eighth grade students remember this topic from their seventh grade science class.

Sixth, ESU#6 focuses on the solar system and the fact that Earth is a small subsystem within the vast and ancient universe. Both Mr. Fox’s students and comparison students perceived themselves knowledgeable about the concepts and
topics regarding ESU#6, including the solar system, motions of the planets in space, motions of the planets, rotation of Earth, and motions of Earth and their relationships to the seasons and tidal changes. All mean scores for self-reported knowledge level for the comparison group were slightly higher than the mean scores for Mr. Fox’s students. However, all pairs of means did not differ significantly between the two groups of students.

When Mr. Fox was dealing with the unit on the weather and the seasons, he taught concepts related to ESU#6, including the sun as an energy source, the effect of the sun on our weather, characteristics of the solar system, and the relationships between motion and tilt of the Earth and seasons and tidal changes. The four main concepts and topics related to ESU#6 were also covered in the science classes of the comparison group. It appears that Mr. Fox’s students and the students in the comparison group had similar exposure to concepts related to ESU#6 and therefore their self-reported knowledge mean scores were not significantly different.

Finally, ESU#7 deals with careers and avocations in sciences that study Earth. The survey (Part III) results indicate that a majority of Mr. Fox’s students agreed that they had more opportunities to learn careers involving Earth systems science. As presented in Chapter 5, when students were engaged in group projects and their own mini-projects, they had more opportunities to learn about scientists’ activities and efforts to understand and investigate the Earth and its subsystems. It seems that Mr. Fox’s students had opportunities to learn about careers related to Earth systems science and were exposed to them throughout the school year.
However, the univariate analysis revealed that Mr. Fox’s students did not significantly differ from the comparison group in their mean score for their self-reported knowledge about “Careers in science.” Mr. Fox’s students had a chance to learn about branches of science when they were in seventh grade. In addition, Mr. Fox’s students learned about careers in Earth systems through their mini-projects and group projects. Regarding the comparison students, the eighth grade science curriculum covered careers related to Earth and space science. Their textbook included explanations and descriptions about Earth and space scientists. Therefore, the results of the univariate analysis regarding careers in science could be explained by the fact that both students studied this topic.

In summary, Mr. Fox’s students reported themselves to be most knowledgeable about how human activities affect Earth systems, motions of Earth and their relationships to the seasons and tidal changes, rotation of Earth, and Value of Earth, whereas changes of Earth systems through interactions of the subsystem and recycling of materials were reported at a least knowledgeable level. In contrast, the comparison group reported themselves to be most knowledgeable about rotation of Earth, motions of Earth and their relationships to the seasons and tidal changes, evolution, and solar system. Changes of Earth systems through interactions of the subsystem and careers in science were reported to be least familiar to students in the comparison group. It appears that both Mr. Fox’s students and the comparison students reported knowledge mean scores on Earth and space science related concepts (e.g., rotation of Earth and motions of Earth) as higher than other concepts.
such as evolution. In particular, Mr. Fox’s students reported a high knowledge level for two ESU-related themes, value of Earth and human activities affect Earth systems.

Among the 23 Earth systems concepts and topics (Survey Part I-3), the mean scores for self-reported knowledge related to four concepts “Value of Earth,” “Interaction of water, land, air, and life,” “Cycles in nature,” “Environmental issues in Columbus (or Ohio),” were significantly higher for Mr. Fox’s students than for the comparison students. Even though the mean scores for only four concepts are significantly different between the two groups, these four concepts and topics reflect one of the major focuses and features of the IESS curriculum and instruction. The concept, “Value of Earth,” is highly associated with the major focus of ESU#1. The topic, “Environmental issues in Columbus (or Ohio),” represents a locally relevant topic and is one of the characteristics of the IESS curriculum. Based on the survey results and other evidence, it seems that Mr. Fox’s students perceived the concepts and themes of the Framework of Seven Earth Systems Understandings throughout the IESS curriculum and instruction. It appears that the focus of the IESS curriculum reflects the ESE Framework as a curriculum framework. The responses of Mr. Fox’s students to the Survey, Part III reflect the concepts and themes of the Earth Systems Understandings.
Students' Perceived Understandings of Earth Systems Concepts and Topics

In Chapter 5, I discussed the MANOVA results related to comparisons between Mr. Fox’s students’ self-reported knowledge and self-perceived significance levels and that of a comparison group. First, the results indicate that the mean scores for self-reported knowledge levels of Mr. Fox’s students were slightly higher than the comparison group. However, the mean differences for the self-reported knowledge level between Mr. Fox’s students and the comparison students were significant for the following 7 of the 13 issues: Acid rain, global warming, loss of biodiversity, ozone hole, pesticides in agriculture, soil erosion, and El Niño. Mr. Fox’s students had higher mean scores compared to the comparison students for all of the topics except loss of biodiversity.

When I examined the science curriculum for the comparison middle school, the following program objectives IV-D in the course, Fundamentals of Science, were related to the topic, “loss of biodiversity.”

- Program Objective IV-D

3. Describe the interactions and dependence of progressively complex biological systems such as niche, habitat, population, community, ecosystem, and biome.

4. Investigate the effects and interactions of organisms on the physical environment.

5. Identify adaptations of organisms in response to their physical environments.
14. Compare reproduction in several different organisms. Explore a variety of sources to identify threats to propagation of organisms.

16. Explore the interactions of organisms and the physical environment.

17. Discuss interrelationships between organisms.


23. Investigate genetically transferable attributes in living organisms, and suggest strategies to maintain diversity organisms through a variety of reproductive strategies.

The seventh grade science curriculum for the comparison school focused on biology and life science. The topics related to diversity organisms, interrelationships between organisms, and human interaction of organisms were covered in the seventh grade science curriculum at the comparison school. In contrast, Mr. Fox’s students had an opportunity to study biodiversity unit and related topics in the eighth grade. Interestingly, even though the eighth grade comparison students did not study this topic, loss of biodiversity, the comparison students had a higher self-reported knowledge mean score for this topic compared to that of Mr. Fox’s students. However, Mr. Fox’s students compared to the comparison students perceived this topic of “loss of biodiversity” to be more significant.
Figure 6.1: Comparisons of self-reported knowledge levels between Mr. Fox’s students and the comparison group based on the results of univariate analysis of variance of the 13 Earth systems and environmental topics.

In examining the mean differences for local and global level issues, such as acid rain, global warming, ozone hole, pesticides in agriculture, soil erosion, and El Niño, Mr. Fox’s students perceived themselves to be more knowledgeable about these environmental issues than the comparison group of students (see Figure 6.1). Based on the findings presented in Chapter 4, IESS-based science topics and units are richly based on student’s real world experiences, local and global environments, and classical and emergent environmental problems. In contrast, the comparison
school for eighth grade science doesn't deal with these local and global environmental topics and issues. Therefore, the results could be explained by the fact that the comparison students did not study the topics and issues associated with local and global environmental topics and issues.

With regard to the self-perceived significance levels on the 13 selected Earth systems and environmental topics, mean differences for the self-perceived significance levels between Mr. Fox’s students and the comparison group were significant for 5 of the 13 issues. All five mean scores for Mr. Fox’s students were significantly higher than the comparison group (see Figure 6.2).

Mr. Fox’s students have higher self-reported knowledge and significance mean scores compared to the comparison students on two global level issues (e.g., global warming and El Niño) and one topic, “pesticides in agriculture.” In addition, the mean score for “Environmental issues in Columbus (or Ohio)” for Mr. Fox’s students is significantly higher than that of the comparison group. These findings suggest that Mr. Fox’s students have higher self-reported knowledge and self-perceived significance levels for some global and local environmental topics and issues. It appears that the IESS curriculum and instruction focuses upon global and local environmental topics and issues and that students become knowledgeable about and perceive the significance of these topics.
Figure 6.2: Comparisons of self-perceived significance levels between Mr. Fox's students and the comparison group based on the results of univariate analysis of variance of the 13 Earth systems and environmental topics.

With regard to students' primary information source for the 13 Earth systems and environmental topics, a majority of Mr. Fox's students (range between 50% - 88%) responded that their primary information source for these topics was their school (class). The comparison students (range between 34% - 63%) responded that their most frequent source for information for 11 of the 13 topics was also school. A notable difference between the two groups is that the school (or class) was considered the primary information source for Mr. Fox's students. In contrast, more comparison students selected TV as the second most frequent source to get
information on these topics and a relatively high number of comparison students chose “Don’t know” as their response to their source of information.

Table 6.1 summarizes the major findings related to the IESS curriculum, Teacher, Mr. Fox’s students, and seven Earth Systems Understandings. Data sources include observation (O), interviews with Mr. Fox (IT), interviews with Mr. Fox’s students (IS), documents analysis (D), personal communication (O), and survey (S).

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<th>IESS Curriculum</th>
<th>Major Findings</th>
<th>Data Source</th>
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<tr>
<td>IESS Curriculum</td>
<td>The IESS curriculum was developed based on a framework of ESE.</td>
<td>D, IT</td>
</tr>
<tr>
<td>ESE provides Mr. Fox with a conceptual approach to curriculum integration.</td>
<td>D, IT</td>
<td></td>
</tr>
<tr>
<td>The IESS curriculum was a grass-roots effort of Mr. Fox and other science teachers in the same middle school.</td>
<td>IT</td>
<td></td>
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<tr>
<td>Most units and classroom activities reflect ideas of ESE and are based on students’ real world experiences.</td>
<td>D, IT</td>
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<tr>
<td>The units and topics are primarily composed of interdisciplinary investigations, locally-relevant topics, and global concepts approached on a regional basis as well as major themes of the Seven Earth Systems Understandings, such as human interactions (or influence) with Earth system and subsystems. In addition, Mr. Fox’s students who had ESE had a significantly higher self-report knowledge mean score for the concept, “Environmental issues in Columbus (or Ohio)” compared to the comparison students who were not exposed to ESE.</td>
<td>D, S, IT</td>
<td></td>
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<tr>
<td>The IESS curriculum proposes the use of extensive fieldwork in the local community as one science teaching method.</td>
<td>D</td>
<td></td>
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<tr>
<td>The IESS curriculum provides well-organized and prepared hands-on experiences and activities. All activities in the field trips are designed for integrating the science disciplines or other subject areas (e.g., mathematics, language arts), and making curriculum connections between science and the real world environment.</td>
<td>D, IT, O</td>
<td></td>
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Table 6.1: Brief summary of major findings and sources of data.
Table 6.1 (continued)

<table>
<thead>
<tr>
<th>Major Findings</th>
<th>Data Source</th>
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<tbody>
<tr>
<td><strong>IESS Curriculum</strong></td>
<td>The mini-projects provide students with extensive and authentic science learning experiences and ample opportunity to increase their computer skills by Internet searching using popular software, word processing, and sometimes doing presentations. The mini-projects also assist students in understanding additional Earth system and science concepts. The mini-projects provide opportunities to expand on what students know.</td>
</tr>
<tr>
<td><strong>Teacher</strong></td>
<td>Mr. Fox holds a constructivist-based philosophy for teaching IESS. He believes that science learning is an active process by the students, facilitated by the teacher. Students are actively constructing new knowledge based on their prior experience, including misconceptions. Thus, Mr. Fox’s teaching and learning strategies are very compatible with recommendations from ESE and constructivist theory. Mr. Fox uses several teaching strategies to identify students’ misconceptions (e.g., concept mapping, brainstorming, open-ended questions). In addition, his major strategies include cooperative learning, inquiry, a jigsaw approach, labs, authentic activities, field trips, and project-based learning. In particular, the use of concept maps, cooperative learning, and authentic activities are primarily based on constructivist learning theory and meaningful learning. Mr. Fox uses appropriate instructional materials and activities from many sources that include locally-relevant or globally-extended topics and content, rather than using a textbook. Mr. Fox uses a variety of assessment strategies as well as open-ended evaluations that allow students to respond in several ways (e.g., group presentations, rubrics, concept mapping, open-ended question). His assessment strategies are very compatible with ESE-based (constructivist-based) teaching and learning strategies and pedagogy. Mr. Fox provides opportunities to engage students in using technology and scientific methods to promote the understanding that Earth systems are interrelated and connected with all sciences. Mr. Fox suggests that the most important benefit is that the IESS curriculum provides authentic-based, hands-on activities and makes connections between students and everyday life experiences. Mr. Fox suggests that time-limitations for field experiences could be one barrier and that not using a textbook could make new science teachers uncomfortable with teaching IESS.</td>
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Table 6.1 (continued)

<table>
<thead>
<tr>
<th>Mr. Fox's Students</th>
<th>Major Findings</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mr. Fox’s students indicate that they are interested in learning about science topics related to their daily lives.</strong> They state that they enjoy and like science learning because they could obtain locally relevant knowledge and apply it to their everyday lives.</td>
<td>IS, O</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Fox’s students agree that what they have learned from science class is important to their real everyday lives and helps them make good decisions in the future.</strong></td>
<td>IS, S</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Fox’s students state that hands-on based experiences and activities during the field trips help them to understand the local environment and nature. Students perceive themselves better able to understand the concepts presented in the lessons by hands-on learning.</strong></td>
<td>IS, S</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Fox’s students are aware of some advantages (or benefits) of using concept maps in their science class. However, students are divided in their views of using the concept map as an evaluation tool. In addition, a majority of Mr. Fox’s students are very satisfied with the teacher’s way of assessing their grades.</strong></td>
<td>IS, S, D</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Fox’s students express that hands-on experiences and science process skills in the field trips are very helpful in learning science and understanding the local environment. Mr. Fox’s students agree that the field trips they have taken this year have been an important part of science class. Furthermore, one student state that learning from the field trips was something different because she could learn from doing, observing, examining, and experiencing things in the real world.</strong></td>
<td>IS, P, O</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Fox’s students agree to some degree that mini-projects and activities in science class are helpful in learning Earth-related science topics. The students agree to some degree that their mini-projects are very helpful in learning other science topics.</strong></td>
<td>S, IS</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Fox’s students agree to some degree that instructional materials provided by the teacher are more efficient than a textbook. Many students state that they liked the teacher’s materials better than a textbook.</strong></td>
<td>S, IS</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Fox’s students perceive themselves to be more knowledgeable about some environmental issues than the comparison group of students. Mr. Fox’s students have higher self-reported knowledge and significance mean scores on two global level issues (e.g., global warming and El Niño) and one topic, “pesticides in agriculture,” compared to the comparison students.</strong></td>
<td>S</td>
<td></td>
</tr>
</tbody>
</table>

(continues)
<table>
<thead>
<tr>
<th>Major Findings</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mr. Fox's Students</strong></td>
<td>School (or class) was considered the primary information source for environmental topics for Mr. Fox's students. The comparison students also state that their most frequent source for information on environmental topics is school. However, the comparison students are more dependent on TV as an information source.</td>
</tr>
<tr>
<td><strong>ESU#1</strong></td>
<td>Mr. Fox's IESS classes and field trips provide an opportunity for students to learn about the Earth through aesthetic experiences and understand the aesthetic qualities and appreciation of the Earth. Mr. Fox's students who had ESE exhibit a higher self-reported knowledge mean score for the theme, &quot;Value of Earth&quot; than the comparison students who were not exposed to ESE. Mr. Fox's students agree that they realize the Earth is a beautiful place and are more interested in nature as a result of their science class.</td>
</tr>
<tr>
<td><strong>ESU#2</strong></td>
<td>Mr. Fox's students agree that they had more opportunities to learn about global environmental issues and topics, human effects on the local environment, and their role in protecting the local and global environment. Mr. Fox's students report that the major theme of ESU#2, &quot;Human activities affect Earth systems&quot; was the one for which they were most knowledgeable and that they felt was most significant compared to the other themes and topics of ESUs.</td>
</tr>
<tr>
<td><strong>ESU#3</strong></td>
<td>Mr. Fox's students express the importance of the use of different scientific methods and technology to understand and study Earth systems, and recognize the nature of Earth systems that connect with all of the science disciplines.</td>
</tr>
<tr>
<td><strong>ESU#4</strong></td>
<td>Mr. Fox’s students who had ESE had a significantly higher self-report knowledge mean score for the concept, “Interaction of water, land, air, and life” compared to the comparison students who were not exposed to ESE. Mr. Fox's teaching and instructional materials focus on the interaction and relationship between Earth system and subsystems. The field trips provide wonderful opportunities for firsthand observations of Earth systems and hands-on experiences and activities related to its subsystems.</td>
</tr>
<tr>
<td><strong>ESU#5</strong></td>
<td>Mr. Fox’s students who had ESE had a significantly higher self-report knowledge mean score for the concept, “Cycles in nature” compared to the comparison students who were not exposed to ESE.</td>
</tr>
</tbody>
</table>

(continues)
Table 6.1 (continued)

<table>
<thead>
<tr>
<th>Major Findings</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESU#6</td>
<td>Mr. Fox’s students perceive themselves knowledgeable about the concepts and topics regarding ESU#6, including the solar system, motions of the planets in space, motions of the planets, rotation of Earth, and motions of Earth and their relationships to the seasons and tidal changes. However, all pairs of means did not differ significantly between Mr. Fox’s students and comparison students.</td>
</tr>
<tr>
<td>ESU#7</td>
<td>Mr. Fox’s students agree that they had more opportunities to learn careers involving Earth systems science. Mr. Fox’s students had more opportunities to learn about scientists’ activities and efforts to understand and investigate the Earth and its subsystems while they were doing mini-projects and group projects in science classes.</td>
</tr>
</tbody>
</table>

Note. Six major data source are used: Observation (O), Interviews with Mr. Fox (IT), Interviews with Mr. Fox’s students (IS), Documents analysis (D), Personal Communication (O), and Survey (S).

Implications

This section discusses the implications of this case study in two subsections. The first subsection discusses the practical implications for science educators that stem from the findings. The second subsection discusses the implications regarding further research.

Implications for Science Educators

The initial reflection I had about Mr. Fox was his confidence and ownership for his IESS curriculum. As observed in the pilot study, the IESS curriculum was a grass-roots effort of Mr. Fox and other science teachers in the same middle school. The Framework of the Seven Earth Systems Understandings and Earth system approach focus and encourage his grass-root efforts in developing the integrated...
science curriculum. He strongly believes that he provides a good starting point and opportunity for his students to learn about science by using an Earth system approach to learning.

As observed in Chapters 4 and 5, the IESS curriculum is primarily focused on locally relevant topics that lead to a global perspective; the interaction of water, land, air, and life (human); and the effect of human activities on Earth systems. The evidence showed that there were many benefits and advantages of the IESS curriculum. Both quantitative and qualitative analyses presented in the previous chapters showed that students liked the content and teaching methods in their science classes and enjoyed Mr. Fox’s teaching style. Thus, science teachers who are interested in redesigning, developing, or reconstructing their integrated science curriculum could consider Mr. Fox’s grass-roots effort and the Earth system approach. Curriculum restructuring at the middle and high schools is not easy. Teachers and administrators should examine a good exemplary case to help guide them through curriculum restructuring. Mr. Fox’s IESS curriculum may be a good example of a local science education reform effort at the middle school level.

Second, Mr. Fox’s viewpoints regarding science teaching and learning are very congruent with constructivist theory and recommendations associated with ESE. He uses a variety of teaching strategies, such as cooperative learning, hands-on learning, project-based learning, and alternative assessment. The IESS curriculum also includes field trips, the use of a variety of technologies, the use of good instructional resources rather than a textbook, and pursuit of student-selected
mini-projects. In particular, the evidence obtained from observations strongly indicates that hands-on learning, project-based learning, and cooperative learning methods make the curriculum more successful and effective. Science teachers could consider strategies recommended by Earth Systems Education (e.g., hands-on learning and cooperative learning) in their curriculum.

Third, Mr. Fox believes that teachers should know what students already know or where students are in their thinking before they start instruction or while they are teaching. He uses several teaching strategies to assess his students’ pre-existing concepts, knowledge, and beliefs: concept maps, brainstorming, and open-ended questions. If science teachers would bring the constructivist teaching ideas (e.g., assessing pre-existing knowledge) into their integration activities, their instruction could be more effective.

Fourth, the results of the survey (Part I-1) presented in Chapter 5 show that Mr. Fox’s students, who had the IESS curriculum and instruction, have higher self-reported knowledge and perceived significance level for some global Earth systems and environmental topics (e.g., acid rain, global warming, ozone hole, pesticides in agriculture, and El Niño) than the comparison students who were never exposed to ESE. In addition, Mr. Fox’s students have a significantly higher self-report knowledge for the concept, “Environmental issues in Columbus (or Ohio)” compared to the comparison students who were not exposed to ESE.

The findings support that Mr. Fox’s locally relevant curriculum meets the needs of students. Mr. Fox’s units and topics are primarily composed of
interdisciplinary investigations, locally relevant topics, and global concepts approached on a regional basis. The IESS curriculum makes connections between students and everyday life experiences. Therefore, the IESS curriculum at Lincoln Middle School could serve as a model for other middle schools in the state or nation as they restructure their science curriculum focusing on the integration of the disciplines and building local relevance for students.

Finally, Rudman (1994) emphasizes the importance of the field trip as a main component of the science curriculum. Both the teacher and the students in this study were very positive about the field trips and believed that they were a very noteworthy part of the IESS curriculum. There were also strong indications, through observations during the field trips and students’ responses after the field trips, that the science field trip experiences had a positive impact on students’ interest in learning about Earth systems and the local environment. Teachers who are teaching science or environmental science should consider science field trips in their curriculum. Science field trips into the local community allow students to overcome the gaps between classroom learning and everyday life.

**Implications for Further Research**

Several findings in this study have implications for future research. First, while ESE has continued to evolve since the first year, 1989, little empirical research has been gathered to evaluate the IESS curriculum in practice. More qualitative and quantitative research should be conducted regarding the effectiveness of IESS
curriculum and instruction. In addition, from the evidence in this study, hands-on and project-based learning and field trips as a part of the curriculum could benefit students' learning and understanding. More research-based information and evidence needs to be gathered regarding the effectiveness of hands-on learning and project-based learning on students' science achievement and attitudes. Regarding field trips, longitudinal research should be conducted on the relationships between field trips and students' cognitive and affective learning outcomes.

Second, IESS curriculum and instruction may have a positive effect on student achievement. However, there has been very limited research with respect to the effects of IESS curriculum and instruction on student achievement and performance. It would be of interest to conduct a comparison study by using a standardized test (e.g., the Ohio standardized proficiency test, ACT, or SAT) to evaluate students' science achievement in an IESS classroom compared to a non-IESS classroom.

Third, more research needs to be conducted on the use of concept mapping as an evaluation tool. As described in Chapter 4, the students seemed to have mixed views related to concept maps. Research clarifying the pros and cons of concept mapping as an instructional method and evaluation tool would be valuable in assisting educators who use it in their classroom.

Fourth, what is the community perception about the effectiveness of the ESE-based program compared to more traditional science curriculum? And is this perception different than students' perception of the ESE-based program?
Fifth, does the amount of ownership of the curriculum felt by teachers who
developed it have anything to do with the effectiveness of the curriculum? Over
time, as these teachers retire and new teachers take over, how will the ownership and
effectiveness of the curriculum change?

Sixth, how might the IESS course affect student selection of universities.
What post-secondary courses do students enroll in and what majors do they pursue?

Seventh, the duplication of this study in other schools, which are employing
the ESE and IESS for teaching students, would help to confirm the evidence found in
this case study. Also, a replication of this study could reveal more or different
evidence related to different populations and different settings.

Eighth, additional instruments could be developed to identify both teacher
and student knowledge of and perceptions of the significance of ESE concepts and
topics. The survey used in this study could be further refined. A factor analysis could
be done on all instruments to identify scales. Of particular interest would be the
relationship between these scales and the Seven Earth Systems Understandings.

Finally, this research was one of the first qualitative and quantitative studies
to focus on ESE and IESS curriculum. This research experience and findings can be
helpful in developing a basic understanding and framework for integrated science
curriculum in Korea. As a first step to create a need for change in Korean science
education, I plan to: (a) assess current Korean science curriculum to identify any
critical components and needs for change; (b) evaluate instructional materials (e.g.,
"Common Science" textbook) to assess how they align with the Earth Systems
Education framework; (c) investigate science teacher’s knowledge and beliefs about learning and teaching integrated science; and (d) explore students’ perceptions and understandings of the major themes and concepts associated with Earth Systems Education.
APPENDIX A

HUMAN SUBJECT APPROVAL LETTER
TITLE PAGE - APPLICATION FOR EXEMPTION
FROM REVIEW BY THE INSTITUTIONAL REVIEW BOARD
The Ohio State University, Columbus OH 43210

PROTOCOL NUMBER: 01 E 0048

---

**Principal Investigator**
Name: David L. Haury
Phone: 614-292-6717

University Title:
- [x] Professor
- [ ] Associate Professor
- [ ] Assistant Professor
- [ ] Instructor
- [ ] Other. Please specify.
(May require prior approval.)

Department or College: School of Teaching & Learning
E-mail: haury.2@osu.edu

Campus Address (room, building, street address): 333 Arps Hall, 1945 North High Street
CAMPUS

Signature: [Signature]
Date: 1-29-01
Fax: 614-292-0263

---

**Co-Investigator**
Name: Rosanne W. Fortner
Phone: 614-292-9826

University Status:
- [x] Faculty
- [ ] Staff
- [ ] Graduate Student
- [ ] Undergraduate Student
- [ ] Other. Please specify.

Campus Address (room, building, street address) or Mailing Address:
210 Kottman Hall, 2021 Coffey Rd
CAMPUS

E-mail: fortner.2@osu.edu

Signature: [Signature]
Date: 2/1/01
Fax: 614-292-7432

---

**Co-Investigator**
Name: Hyonyong Lee
Phone: 614-292-1078

University Status:
- [x] Faculty
- [ ] Staff
- [ ] Graduate Student
- [ ] Undergraduate Student
- [ ] Other. Please specify.

Campus Address (room, building, street address) or Mailing Address:
210 Kottman Hall, 2021 Coffey Rd
CAMPUS

E-mail: lee.1503@osu.edu

Signature: [Signature]
Date: 01/29/01
Fax: 614-292-7432

---

**Protocol Title**
A Case Study of Science Curriculum Integration: Earth Systems Approach

**Source of Funding**
Personal Funds

---

For Office Use Only:
- [x] Approved. ► Research has been determined to be exempt under these categories:
Research may begin as of the date of determination listed below.

- [ ] Disapproved. ► The proposed research does not fall within the categories of exemption. Submit an application to the appropriate Institutional Review Board for review.

Date of determination: 2/6/2001
Signature: [Signature]
Office of Research Risks Protection

---

HSE-1.0  Page 2  Approved by the Policy Coordinating IRB, May 18, 2000

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APPENDIX B

INFORMATION LETTER FOR PARENT/GUARDIAN
January 23, 2001

Dear Parent/Guardian:

We are writing to request your permission, and that of your child, to participate in a "Case Study of Science Curriculum Integration: Earth Systems Approach." This research has received the approval of Mr. Harley Williams, Principal of LincolnMiddle School, and Mr. Fox. Mr. Fox is very familiar with Earth Systems Education as a new integrated science curriculum and is currently using teaching strategies associated with Earth Systems Education in his science classes. In brief, Earth Systems Education (ESE) is a new model of science teaching and learning that studies Earth as a system of many interacting subsystems and focuses on the changes within and between subsystems of water, land, air, ice, and life. We are interested to study the instruction and curriculum provided by the teacher, and some of the barriers or difficulties with teaching an ESE model. Therefore, this case study will primarily focus on the teacher. Mr. Hyonyong Lee, a doctoral candidate at The Ohio State University, Dr. Rosanne W. Fortner, a Professor at The Ohio State University, and Dr. David L. Haury, an Associate Professor at The Ohio State University, will be conducting this study.

Mr. Hyonyong Lee will be present in the classroom throughout the rest of the 2000-2001 academic year to observe science lessons taught by Mr. Fox to interact with the students, and to videotape the classroom activities that occur during classes. As mentioned above, the major purpose of this study is to investigate how Mr. Fox facilitates science learning through ESE curriculum and instruction in natural contexts. However, your child may also be selected to participate in up to two interviews conducted during the school day (e.g., during lunch or a scheduled study period) in order to observe students' understanding of science and planet Earth. Your child will not be asked to participate in any activities related to this study that require time outside the regular school day nor any assignments planned by Mr. Fox. Information collected during this study will not be made available to the administration at LincolnMiddle School or used by Mr. Fox to evaluate the performance of your child when assigning grades.

Students participating in this study will not be identified by name in any oral or published reports of the study. In addition, the name and location of the school will be altered to ensure anonymity. Your child may withdraw from participation in the study, without penalty, by contacting Mr. Hyonyong Lee or Mr. Fox.
Respectfully,

Dr. Rosanne W. Fortner
210 Kottman Hall
2021 Coffey Road
Columbus, OH 43210
614.292.9826
fortner.2@osu.edu

Dr. David L. Haury
333 Arps Hall
1945 N. High Street
Columbus, OH 43210
614.292.6717
haury.2@osu.edu

Hyonyong Lee
210 Kottman Hall
2021 Coffey Road
Columbus, OH 43210
614.292.1078
lee.1503@osu.edu
Drs. Rosanne W. Fortner and David L. Haury, and Mr. Hyonyong Lee are interested in studying how Mr. Fox teaches science based on Earth Systems Education, and how students learn science. We invite you to participate in a research study titled "A Case Study of Science Curriculum Integration: Earth Systems Approach" that will attempt to understand the new integrated earth systems science. In order for us to conduct this study we would like to be in the classroom to observe instruction and interact with you, your classmates, and Mr. Fox during your regular science class. We may be talking to you during the class and collecting audio and videotape recordings of your discussions, and activities during the science class. Some students may also be asked to participate in up to two individual interviews about how they are learning science. Our involvement in your science class will last for the rest of the 2000-2001 academic year.

We would very much appreciate your agreement to participate in this study. You may end your participation in the study at any time by telling any of the people listed below or Mr. Fox.

Please sign your name in the space below and have your parent or guardian sign if you agree to participate in the study. This form should be returned to Mr. Fox by the end of the week. If you have any questions about this study, feel free to contact Drs. Rosanne W. Fortner, David L. Haury, or Hyonyong Lee at the phone numbers or e-mail addresses below.

Information for Parent or Guardians
- This study has the approval of Mr. Harley Williams and Mr. Fox.
- No student will be identified in any documents or publications resulting from this study.
- The study will occur throughout the rest of the 2000-2001 academic year
- We will evaluate no student for the purpose of assigning grades and we will not influence grades given by Mr. Fox.
- A copy of the results of this study will be made available to Lincoln Middle School or Mr. Fox.
- Both signatures, from you and your child, are required.
We will explain the purpose of this study to your child in Mr. Fox's class and describe what participation in the study might require. If you are willing to grant permission, and if your child is willing to participate, please sign the Participant Agreement Form attached to this letter and return it to Mr. Fox as soon as possible. It is necessary that both you and your child sign the form in the spaces indicated. Keep this letter for your records. If you have any questions about this study, feel free to contact any of the researchers at the phone numbers or e-mail addresses below.

Sincerely,

Dr. Rosanne W. Fortner
210 Kottman Hall
2021 Coffey Road
Columbus, OH 43210
614.292.9826
fortner.2@osu.edu

Dr. David L. Haury
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1945 N. High Street
Columbus, OH 43210
614.292.6717
haury.2@osu.edu

Hyonyong Lee
210 Kottman Hall
2021 Coffey Road
Columbus, OH 43210
614.292.1078
lee.1503@osu.edu

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APPENDIX D

CONSENT FORM FOR PARTICIPATION IN RESEARCH
CONSENT FOR PARTICIPATION IN RESEARCH

I consent to participating in (or my child's participation in) research entitled: A Case Study of Science Curriculum Integration: Earth Systems Approach.

Drs. David L. Haury, and Rosanne W. Fortner, Principal Investigator, or his/her authorized representative Hyonyong Lee has explained the purpose of the study, the procedures to be followed, and the expected duration of my (my child's) participation. Possible benefits of the study have been described, as have alternative procedures, if such procedures are applicable and available.

I acknowledge that I have had the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that I am (my child is) free to withdraw consent at any time and to discontinue participation in the study without prejudice to me (my child).

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ____________________________  Signed: ____________________________

(Participant)

Signed: ____________________________  Signed: ____________________________

(Principal investigator or his/her authorized representative)

(Person authorized to consent for participant, if required)

Witness: ____________________________

HS-017E Consent for Participation in Exempt Research
Office of Academic Services 614-292-2332
Integrated Teaching and Learning 614-292-0135
Language, Literacy, and Culture 614-292-0711 or 614-292-2445
Mathematics, Science, and Technology Education 614-292-8765

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APPENDIX E

BACKGROUND INFORMATION FORM
Background Information Form

1. Personal Information

Name: __________________________
Year of Birth: ___________________
Gender: _______
School Phone: ____________________ Home Phone: ____________________
Email Address: ___________________________

2. Education

<table>
<thead>
<tr>
<th>Degree Awarded (B.A., M.A., etc.)</th>
<th>Major Field</th>
<th>Date</th>
<th>Name of University/College</th>
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3. Teaching Certification

<table>
<thead>
<tr>
<th>Grade(s)</th>
<th>Discipline</th>
<th>Date of Certification</th>
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4. Current Teaching Position

Grade Level ____________________
Discipline ____________________
Number of Years Teaching this Subject at this Grade Level ________

5. Past Teaching Experience

<table>
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<th>Beginning-Ending (Month/Year)</th>
<th>Grade Level</th>
<th>Subject(s)</th>
<th>Number of Years</th>
</tr>
</thead>
</table>

6. Professional Organizations

Affiliations with Professional Organizations such as NSTA, NARST, AERA,...

<table>
<thead>
<tr>
<th>Name of Organization</th>
<th>Date(s) of Membership</th>
</tr>
</thead>
</table>

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APPENDIX F

INTERVIEW PROTOCOL #1 USED WITH MR. FOX
Thank you so much for your willingness to participate and be interviewed here. I have been studying integrated science curriculum and Earth Systems Education (ESE). I would like to talk about your science teaching and ESE. All your answers will be kept strictly confidential. I would like to videotape the interview to make sure that I do not miss anything. I will be the only person who has direct access to the tape. If part of what you say is included in any report or publication, it will be presented anonymously. You will have a chance to review a transcript of this interview if you want, before any report or publication is written. In fact, I would encourage you to do so. Do you have any questions before I begin?

Views on ESE and Seven understanding (Framework)

I heard that all science teachers in this middle school teach science on the basis of Earth Systems Education.

Q: What are your general perceptions about ESE as an integrated science program or curriculum?

Q: What do you think is the most important feature of ESE, compared to other science curriculum efforts or programs?

Q: What do think about using system approach (or Earth system approach) in science education at the middle school?

Q: What do you think about seven understanding as a curriculum framework? How does the Framework of Seven Earth Systems Understandings of ESE influence the curriculum and instruction?

Q: Can you explain all reasons or factors that led the school to teach science with an Earth system approach?

Q: What are the advantages for a teacher, as you see it, to teaching science as an integrated discipline?
Q: In what ways do you think students' benefit from your Integrated Earth Systems Science (IESS) curriculum?

Q: What do you perceive to be some of the barriers or difficulties in teaching with an Earth system approach?

[How have you [science teachers in your school] overcome these barriers?]

Q: Generally, What kinds of instructional resources (including instructional technology) do you use for science class?

Views on Constructivism

Many of ESE ideas about teaching and learning processes are based on constructivist ideas or constructivist learning theories. Each component of ESE teaching and learning strategies includes student-centered instruction facilitated by the teacher, productive group interaction (Cooperative learning) during the learning process, authentic classroom tasks (introduction of a real-world problem), evaluations (concept mapping, etc), the teacher as facilitator and resource provider, and most importantly, the students as agents of the classroom environment and learning.

Q: What is your view about constructivist ideas (or constructivist teaching & learning theories)? How do you feel about constructivist learning/teaching environments?

Q: What do you think about ESE-based teaching and learning strategies in your science class?

Q: Your opinions about cooperative learning (working as a group) and real-life based hands-on activity?

Q: Do you have particular instructional strategies to promote students' integrated science learning?

Field Trip

I heard that you had several field trips and outdoor education, such as Tar Hollow, Big Darby, Pickerington Ponds Field Trip.

Q: Did you enjoy teaching science on the trip? Why?
Q: What did you experience as a teacher?

Q: Can you tell me about the field trip? Any advantages, benefits or disadvantages (or difficulties)?

**Evaluation (including Concept Mapping)**

Q: What do you think about your grading systems?

Q: Could you explain about your major assessment methods?

Q: What do you think about concept mapping in your classroom? Do you think that it is important way of assessing students’ grading? Why? Any good advantages or disadvantages?

**Curriculum and Instruction**

Q: Could you tell me how to decide all units and topics in your seventh and eighth curriculum in your school?

Q: Could you explain about characteristics of all units and topics?

Q: What do you think about your mini-projects?
APPENDIX G

WRITTEN QUESTIONS USED WITH MR. FOX
WRITTEN QUESTIONS USED WITH MR. FOX

Q: What are your general perceptions about ESE as an integrated science program or curriculum?

Q: What do you think is the most important feature of ESE, compared to other science curriculum efforts or programs?

Q: Could you explain all reasons or factors that led you to teach science with an Earth system approach or integrated science approach?

Q: In what ways do you think students' benefit from your Integrated Earth Systems Science (IESS) curriculum?

Q: What do you perceive to be some of the barriers or difficulties in teaching with an Earth system approach?

Q: What is your perception about constructivist ideas?

Q: What do you think about ESE-based teaching and learning strategies in your science class?

Q: Could you explain about your major assessment methods?

Q: Your opinions about cooperative learning (working as a group) and real-life based hands-on activity?

Q: Could you tell me how you determined the units and topics in your seventh and eighth curriculum in your school?

Q: Could you explain about characteristics of all units and topics?

Q: What do you think about your mini-projects?

Q: Your opinions or feeling about a good science teacher?

Q: Can you tell me about the field trip? Any advantages, benefits or disadvantages (or difficulties)?
APPENDIX H

INTERVIEW PROTOCOL #2 USED WITH STUDENTS
INTERVIEW PROTOCOL #2 USED WITH STUDENTS

Date: ___/___/____
Student’s Name: ______________

Hi [Student’s Name]!!

Thank you so much for your willingness to participate and be interviewed here. I have been studying integrated science curriculum and Earth Systems Education (ESE). Currently, I'm interested in students' understanding about earth systems, and their opinions about science class based on earth systems.

I would like to talk about your science learning and teacher. All your answers will be kept strictly confidential. I would like to videotape the interview to make sure that I do not miss anything. Is that all right with you?

I will be the only person who has direct access to the tape. If part of what you say is included in any report or publication, it will be presented anonymously. You will have a chance to review a transcript of this interview if you want, before any report or publication is written. In fact, I would encourage you to do so. Do you have any questions before I begin?

Please try to remember science class, learning and everything during this academic year.

[Note: I can indicate specific unit]
[Units are Changeable depending on what they have learned; Option: You have learned watershed, wetlands, biodiversity, climate change (global warming), El Nino, plate tectonics, Ohio's natural resources, environmental issues, evolution, and so on. Are you able to remember learning about these things?]

Views about science learning

Q: What kind of science did you have in school last year? Did you enjoy it? How does it compare with this year’s science? Do you enjoy ESE? Why or why not?

Q: What is your favorite unit or topic in science class this year?

[If they seem puzzled, provide examples]

Q: [global warming], Tell me why you like [global warming]?

Q: How has [global warming] affected our earth systems? and other subsystems on Earth?
Q: Is human activity affecting [global warming]?

Q: Can you explain how human activity affects [global warming]?

Q: Can you explain why [global warming] is important to humans.

Q: Can you describe how [global warming] has changed over time?

Q: Generally, what do you think about the unit and topic that you have learned about?

[Note: questions will be slightly different depending on students' answers]

[If needed, 
Can you give a more detailed description of what you studied or how? 
Do you have other examples of [ ]? 
Explain how [ ] can affect [ ]?

Views about Instructional Materials and Grading

I know you have no textbook, but, your teacher provides handouts, activities, and materials.

Q: What do you think about having no textbook?

Q: Do you enjoy and like the instructional materials?

Next, I am going to ask you about grading. According to your syllabus, your science grade is based on all assignments, tests, quizzes and projects.

Q: What do you think about his way of assessing your grade?

For example, using concept maps
Q: Do you like concept maps? Why? 
   Do concept maps help put ideas together?

Q: Do you worry about your grade in science? Do you know how you are doing in science most of this time?

I know you have an oral presentation for your mini-project. I heard that you can decide any science topic.

Q: What is your recent topic?
Q: How did you prepare for your presentation?

Q: What did you enjoy [or learn] about your mini-project?

**Views about Field Trip**

I know that you had several field trips and outdoor education, such as Tar Hollow, Big Darby, Pickerington Ponds Field Trip. Choose one and tell me about it.

Q: Did you enjoy the trip? What did you experience on the trip?

Q: Can you tell me more about the most interesting things related [ ]?

Q: What kinds of science activities did you do?

Q: Could you have learned the same things in class?

Q: What will you remember most about learning outside of school?

Thank you so much for your assistance!!!
Observation Field Notes

Observation date:
Time:
Site:
Before observation:

<table>
<thead>
<tr>
<th>During observation:</th>
<th>My Reaction &amp; Reflection (Methodology, Theory, etc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation Notes</td>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After observation:

266

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Questionnaire to Survey Middle School Students' Understanding About Earth Systems Concepts (or Topics) and Earth Systems Education

This questionnaire is designed to investigate how well middle school students understand earth systems concepts (or topics) and Earth Systems Education. Please answer all of the questions and return it to me (or the teacher) directly. Your information is used only for our study and **NO ONE** can see your answers or find out what you tell us. We greatly appreciate your assistance.

### PART I

1. By circling one of the six numbers, please indicate **how knowledgeable** you think you are about each of the following Earth systems and environmental topics (or issues), and indicate **how significant** you think each of the following topics is.

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Problems</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all</td>
<td>1 2 3 4 5 6</td>
<td>Very trivial</td>
</tr>
<tr>
<td>Very knowledgeable</td>
<td>Acid rain</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Air pollution</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Deforestation</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Water pollution</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Global warming</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Introduced species</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Loss of biodiversity</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Oil spills</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Ozone hole</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Pesticides in agriculture</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Soil erosion</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>Trash disposal</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>El Niño</td>
<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>
2. Please circle **one source** from which you get the most information from on each of the following environmental issues.

![Table of Information Sources](image)

<table>
<thead>
<tr>
<th>Problem</th>
<th>School</th>
<th>Parents</th>
<th>TV</th>
<th>Internet</th>
<th>Newspapers</th>
<th>Books</th>
<th>Magazines</th>
<th>Radio</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid rain</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
</tr>
<tr>
<td>Air pollution</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
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<tr>
<td>Deforestation</td>
<td>S</td>
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<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
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<tr>
<td>Water pollution</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
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<td>M</td>
<td>R</td>
<td>D</td>
</tr>
<tr>
<td>Global warming</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
</tr>
<tr>
<td>Introduced species</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
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<tr>
<td>Loss of Biodiversity</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
</tr>
<tr>
<td>Oil spills</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
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<tr>
<td>Ozone hole</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
</tr>
<tr>
<td>Pesticides in agriculture</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
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<tr>
<td>Soil erosion</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
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<tr>
<td>Trash disposal</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
</tr>
<tr>
<td>El Niño</td>
<td>S</td>
<td>P</td>
<td>T</td>
<td>I</td>
<td>N</td>
<td>B</td>
<td>M</td>
<td>R</td>
<td>D</td>
</tr>
</tbody>
</table>
3. By circling **one of the six numbers**, please indicate **how much you know** about each of the following science concepts or topics, that is, **how knowledgeable** you are. And, indicate **how significant** you think each of the following science concepts is.

<table>
<thead>
<tr>
<th>Knowledge (Your Understanding)</th>
<th>Content Knowledge and Topics</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all</td>
<td>Very knowledgeable</td>
<td>Very trivial</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>1. Value (or beauty) of Earth</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>2. Human activities' affect on Earth systems</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>3. Use of technology for study of science</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>4. Interaction of water, land, air, and life</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>5. Earth history</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>6. Plate tectonics processes</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>7. Structure of the solid Earth</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>8. Catastrophic events and their impacts on Earth systems</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>9. Evolution</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>10. Fossil evidence</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>11. Solar system</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>12. Recycling of materials</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>13. Changes of Earth systems through interactions of the subsystem</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>14. Cycles in nature (water cycle, rock cycle, etc.)</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>15. Motions of the planets</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>16. Rotation of Earth</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>17. Ecosystems (local community)</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>18. Motions of Earth and their relationships to the seasons and tidal changes</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>19. Careers in science</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>20. Urban watersheds</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>21. Ohio's natural resource</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>22. Ohio's geology</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1 2 3 4 5 6</td>
<td>23. Environmental issues in Columbus (or Ohio)</td>
<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>
PART II

DIRECTION: Read carefully each of the following statements, and rate how much do you agree or disagree with the statement on a 1-6 scale, where 1 = Strongly Disagree (SD), 2 = Disagree, 3 = Slightly Disagree, 4 = Slightly Agree, 5 = Agree, and 6 = Strongly Agree (SA). There are no right or wrong answers.

<table>
<thead>
<tr>
<th>STATEMENTS</th>
<th>SD</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Earth is a beautiful place.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2. One of the things that interests me the most about science are the beautiful parts of the Earth that I have encountered.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3. I appreciate the Earth more now than I did a year ago.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4. It is difficult studying the Earth without knowing some biology, chemistry, or physics.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5. It is difficult understanding the Earth without knowing the interacting subsystems of water, rock, ice, air, and life.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6. I like to use actual environmental problems and phenomena to learn about science in science class (e.g., El Niño, Ozone Hole, Global warming).</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7. I like studying about the Earth and the other parts of Earth (its subsystems) at the same time.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8. Combining information from all of the scientists and technicians makes solving problems about the Earth easier.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9. When I try to solve a problem in science class, I often use information from more than one area of science.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10. I really like studying about how humans manage our limited resources, reduce consumption, and recycle the resources in my local area.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>11. As a result of my science class, I often notice how human activity affects my local environment.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>12. I would prefer to learn about science from a global perspective rather than from local examples.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>13. I do not like to use a textbook to learn science.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>14. As a result of my science class, I pay more attention to the natural world around me.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>15. As a result of my science class, I am more aware of the effects that I have on the local environment.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>16. As a result of my science class, I am better able to use computers and other technology to help solve problems.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>17. Using technology and a variety of scientific methods are very valuable parts of learning about Earth systems.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>18.</td>
<td>Interacting in a group with other students helps me to learn about science</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>19.</td>
<td>It is easier for me to learn science when I work in a team.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>20.</td>
<td>As a result of my science class, I think that scientists from many different countries should collaborate to study the Earth's origin, processes, and evolution.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>21.</td>
<td>As a result of my science class, I am more aware that there are many careers involving Earth systems science that are open to girls and boys.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>22.</td>
<td>Many of the things we have studied in science class are important to my everyday life.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>23.</td>
<td>What we have done in science class will help me make good decisions in the future about environmental problems such as global warming.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>24.</td>
<td>Working on projects (including mini-projects) and activities in science class helps me learn about Earth and science</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>25.</td>
<td>Drawing concept maps in science class helps me to put science concepts (or ideas) together.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>26.</td>
<td>The field trips we have taken this year have been an important part of science class.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>27.</td>
<td>Science field trips help me understand the local environmental and science concepts that I have learned.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>28.</td>
<td>Environmental change usually occurs as a result of human interactions with Earth systems.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>29.</td>
<td>As a result of my science class, I have more opportunities to learn about global environmental issues and problems, and my role in protecting the local and global environment.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>30.</td>
<td>As a result of my science class, it is easier to see the ways in which water, air, land and life interact.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>31.</td>
<td>As a result of my science class, I often recognize that the Earth subsystems are continually changing through natural cycles and processes.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>32.</td>
<td>When we learn science, it is important to find connections between the science disciplines.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>33.</td>
<td>Using concept maps in my quizzes and tests is an appropriate method to assess my knowledge.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>34.</td>
<td>In our class, I like my science teacher's styles of teaching science and the learning about activities he has provided.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>35.</td>
<td>My mini-projects on a science topic of my choice are very helpful in learning other science topics.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>36.</td>
<td>Using the science materials and handouts that the science teacher provided are more efficient than using a textbook.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>37.</td>
<td>My science teacher's way of assessing my grade is fair and satisfying.</td>
<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>
• Gender: Male_____; Female_______

• Year of birth: _________

• Approximate overall letter grade in 8th grade science: A B C D E F

Thank you very much for your assistance!!  ^_^
APPENDIX K

TEACHER'S INSTRUCTIONAL AND EVALUATION MATERIALS FOR THE TOPIC EL NIÑO
1. What has more impact on climate than El Niño?
2. What controls most of the climate on Earth?
3. How often does El Niño happen?
4. How does El Niño form?
5. What do scientists do to study El Niño?
6. How many buoys are used to study El Niño?
7. How do Peruvian fishers know when El Niño has arrived?
8. How does El Niño affect weather on land in Peru?
9. How do we know when El Niño is starting?
10. How do scientists make an El Niño forecast?
11. What happens to the temperature of surface water in the eastern Pacific Ocean during an El Niño?
12. Where do heavy rains occur as a result of El Niño?
13. Where do droughts occur as a result of El Niño?
14. Why do certain areas get more rainfall during an El Niño?
15. Why does El Niño affect weather and climate in the United States?
16. How is California affected by El Niño?
17. What is a positive benefit of El Niño in the Atlantic Ocean?
18. How does El Niño weather in the northern United States?
19. How do we know that El Niño has occurred in the past?
20. How can tree rings be used to study El Niños of the past?
21. How are organisms in the Galapagos Islands affected by El Niño?
22. How has El Niño affected the populations of finches in the Galapagos?
23. For how long have El Niños been happening?
El Niño Research Questions

For Group 1
Why is it called El Niño? La Niña? What is El Viejo? ENSO?
How are El Niño and La Niña related? How are they the same? Different?

For Group 2
What causes El Niño? How does it form?
What does it occur only in the Pacific Ocean and near the Equator?
What determines how big an El Niño is?
How long do El Niño last? Is it always the same? How often do they occur?

For Group 3
How do scientists study El Niño?
What do buoys measure about El Niño?

For Group 4
How is the intensity and frequency of El Niño changing?
Is global warming having an effect on El Niño?
What are the positive effects of El Niño? Where do they occur?
What are the long term effects of El Niño?

For Group 5
How does El Niño affect the areas close to it?
How does El Niño affect other areas on Earth and how much?

For Group 6
What is the history of El Niño? What evidence is used to discover this?
How are El Niños predicted? When will the next one occur?
How can El Niño be modeled? By scientists? By us?
### El Niño Rubric

**NAME ________**

**PER ________**

---

**Points out of 12.**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Tues., 2/6</th>
<th>Weds, 2/7</th>
<th>Fri., 2/9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very cooperative, Helps lead group, Works entire period.</td>
<td>4 Pts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooperative Works 90% of time, Follows lead well.</td>
<td>3 Pts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Works 75% of time, Has to be told what to do.</td>
<td>2 Pts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argues a little, Works about half the period.</td>
<td>1 Pts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncooperative, Argues about things, Does little work.</td>
<td>0 Pts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Grade =**

Individual Contribution ____ + Group Oral Presentation ____ = ____ out of 62.
<table>
<thead>
<tr>
<th>Appropriate Handout</th>
<th>Information Complete.</th>
<th>Most Information Included.</th>
<th>About 50% of Information Included.</th>
<th>Little Information. Hard to Read.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legible.</td>
<td>Not very legible.</td>
<td>Legible.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Pts.</td>
<td>8-9 Pts.</td>
<td>7 Pts.</td>
<td></td>
<td>1-3 Pts.</td>
</tr>
<tr>
<td>Visuals</td>
<td>Complete &amp; Accurate.</td>
<td>Most of the Information is Presented.</td>
<td>About 50% of Information Presented.</td>
<td>Little Information. Given to Answer Questions</td>
</tr>
<tr>
<td>Legible.</td>
<td>Complete Information.</td>
<td>Less Legibility.</td>
<td></td>
<td>1-3 Pts.</td>
</tr>
<tr>
<td>10 Pts.</td>
<td>8-9 Pts.</td>
<td>7 Pts.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye Contact</td>
<td>Talk Directly to Class</td>
<td>Talk to Class 75% of Time.</td>
<td>Talk to Class 50% of Time.</td>
<td>Talk to Class 25% of Time.</td>
</tr>
<tr>
<td></td>
<td>5 Pts.</td>
<td>4 Pts.</td>
<td>3 Pts.</td>
<td>2 Pts.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>Sequence of Information Makes Sense</td>
<td>Some Hesitation from One Person to the Next.</td>
<td>&quot;Jump&quot; Around from One Thing to Another.</td>
<td>Very Disorganized.</td>
</tr>
<tr>
<td></td>
<td>5 Pts.</td>
<td>4 Pts.</td>
<td>3 Pts.</td>
<td>1-2 Pts.</td>
</tr>
<tr>
<td>Research Questions Answered</td>
<td>Very Well. Very Complete.</td>
<td>90% to 95% Answered.</td>
<td>75% Answered.</td>
<td>50% Answered.</td>
</tr>
<tr>
<td></td>
<td>15 Pts.</td>
<td>12-14 Pts.</td>
<td>10-11 Pts.</td>
<td>6-9 Pts.</td>
</tr>
<tr>
<td>All Participate in</td>
<td>All Members Participate Well and Equally.</td>
<td>Most Members Participate Well.</td>
<td>One or Two Dominate.</td>
<td>One Person Does Everything.</td>
</tr>
<tr>
<td>Presentation</td>
<td>5 Pts.</td>
<td>3-4 Pts.</td>
<td>2 Pts.</td>
<td>1 Pts.</td>
</tr>
</tbody>
</table>

Points out of 50.
Science Grade 8  
**Quiz**  
36 Points

<table>
<thead>
<tr>
<th>NAME</th>
<th>PER</th>
<th>DATE</th>
</tr>
</thead>
</table>

1. What do the terms El Niño and La Niña mean? Why are the events called El Niño and La Niña? (6 pts.)

2. Describe how El Niño forms (include where it forms). (10 pts.)

3. Describe how La Niña forms. (8 pts.)

4. How often (on average) does El Niño occur? How long does it last? (4 pts.)

5. Describe two effects that El Niño has. Be specific about what happens and where it happens. (8 pts.)

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APPENDIX L

EXAMPLE OF FIELD TRIP HANDOUT
(BATTELLE-DARBY METRO PARK)
AREA A - STREAM LIFE AND WATER QUALITY

During your visit to the stream you will be investigating the variety of life found in and around the stream as well as testing the biological water quality.

Part I - Biotic factors of the stream
Describe the area immediately adjacent to (next to) the stream. Include the obvious kinds of organisms that live there.

It's very muddy with lots of rocks and little insects, grass, and dead trees

Using the tools and techniques demonstrated, collect and identify the macroinvertebrates found in the stream. Record your findings on the back of this sheet. When you have all of the data, figure out the stream quality index. Use the instructions on the bottom of the back of this sheet.

Part II - Explain how the quality of the water in the Big Darby is related to the trees on each side of the stream and the type of rocks found in the stream bed.

The trees soak up the chemicals from the farms keeping the stream healthy
**Part III - Water Quality Testing**

You will be assigned a particular test to perform on a sample of the stream water. Using the test kits and instructions collect your data. Record it in the appropriate space below. When everyone is finished results will be shared.

<table>
<thead>
<tr>
<th></th>
<th>Dissolved Oxygen 6 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
<td>7.6</td>
</tr>
<tr>
<td>Nitrates</td>
<td>3</td>
</tr>
<tr>
<td>Phosphates</td>
<td>0.1</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>don't do</td>
</tr>
<tr>
<td>Hardness (TDS)</td>
<td>4.25 (mg/L)</td>
</tr>
<tr>
<td>Water Temperature</td>
<td>14°C</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>20°C</td>
</tr>
</tbody>
</table>

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**AREA B - STREAM CHARACTERISTICS**

During your visit to the stream you will be identifying the different types of rocks that are found in the stream bed. You will also make a map of the stream indicating the different materials that make up the bed of the stream. You will figure out where the rocks you find originated and will figure out how much water is in the stream and how fast it is moving.

**Part I - Rock identification**

Fill out the following chart as you study and identify your twenty rocks (Select 20 rocks for the entire group to use. They may already be selected for you). Use the rock key.

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Rock Names</th>
<th>How many?</th>
<th>Group Total</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedimentary</td>
<td>Sandstone</td>
<td></td>
<td>9</td>
<td>Ohio</td>
</tr>
<tr>
<td></td>
<td>Limestone</td>
<td></td>
<td>8</td>
<td>Ohio</td>
</tr>
<tr>
<td></td>
<td>Dolostone</td>
<td></td>
<td>3</td>
<td>Ohio</td>
</tr>
<tr>
<td></td>
<td>Flint</td>
<td></td>
<td>7</td>
<td>Ohio</td>
</tr>
<tr>
<td></td>
<td>Shale</td>
<td></td>
<td></td>
<td>Ohio</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metamorphic</td>
<td>Gneiss</td>
<td></td>
<td>1</td>
<td>Canada</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Igneous</td>
<td>Granite</td>
<td></td>
<td>9</td>
<td>Canada</td>
</tr>
<tr>
<td></td>
<td>Diorite</td>
<td></td>
<td>5</td>
<td>Canada</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mark down the types of rocks discovered by each of the students in the stream.
**Part II - Mapping the stream bed**

Make a profile of the stream on the separate sheet of paper based on the depths measured and the width of the stream (on separate graph paper).

**Part III - Calculating the velocity of the stream**

Describe below the procedure used to calculate stream velocity and record the value below.

\[
\text{Stream velocity } \frac{20}{19} \text{ meters per second (m/s)}
\]

Using the profile, calculate the average depth of the stream.

\[
\text{Average depth } = \frac{63}{100} \text{ meters (m)}
\]

Now calculate the area of the stream in profile.

\[
\text{Profile area } = \frac{1366}{1000} \text{ sq. meters (m}^2\text{)}
\]

Multiply this by the velocity to get the discharge. Put in the appropriate units for the discharge.

\[
\text{Discharge} = \frac{146}{1000} \text{ m}^3/\text{s}
\]

There is a corridor of trees along both sides of the creek. Explain how this corridor of trees helps to preserve the water quality of Big Darby Creek. Most of the land surrounding the park is farmland.

They soak up the runoff from the farms. This prevents chemicals from entering the creek.
This line refers to the top of the water.
Rock Identification Key

Use this key to help you identify the rocks found in the stream bed at Blacklick Metro Park.

Look at the minerals that the rock is made of. Do not pay any attention to any dirt that might be on the rock.

1. Is there more than one kind of mineral (color) in the rock?  
   If yes, go to number 2.  If no, go to number 4.

2. Are there black stripes in the rock?  If yes, it is GNEISS  
   If no, go to number 3.

3. Pink, black and white minerals in the rock.  GRANITE  
   Black and white minerals only.  DIORITE

4. Feels rough and you can scrape off some sand.  SANDSTONE  
   Put acid on it and it fizzes. (usually a gray color)  LIMESTONE  
   Can't see it fizz, but you can hear it fizz. (usually gray)  DOLOSTONE  
   Dull, smooth sides with some sharp edges.  FLINT  
   Flat and dark and breaks apart easily.  SHALE
AREA C - NATURE TRAIL WALKABOUT

On this walk you will look at the organisms living along the nature trail and record the ones that you find. You will also take a small soil sample to be tested later and will determine air temperatures in a couple of places.

Part 1 - Organisms Found

<table>
<thead>
<tr>
<th>Organism Type (plant or animal)</th>
<th>Organism Name</th>
<th>Where found?</th>
<th>How many? (in 4 m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal</td>
<td>tent caterpillar</td>
<td>on tree</td>
<td>100</td>
</tr>
<tr>
<td>Plant</td>
<td>wild cherry tree</td>
<td>path edge</td>
<td>a few</td>
</tr>
<tr>
<td>Plant</td>
<td>viburnum</td>
<td>path edge</td>
<td>5</td>
</tr>
<tr>
<td>Plant</td>
<td>poison ivy</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Plant</td>
<td>multiflora rose</td>
<td></td>
<td>lots</td>
</tr>
<tr>
<td>Plant</td>
<td>goldenrod/insect grill</td>
<td></td>
<td>lots</td>
</tr>
<tr>
<td>Plant</td>
<td>box elder</td>
<td></td>
<td>lots</td>
</tr>
<tr>
<td>Plant</td>
<td>teasel</td>
<td></td>
<td>some</td>
</tr>
<tr>
<td>Plant</td>
<td>thorny locust</td>
<td></td>
<td>a couple</td>
</tr>
<tr>
<td>Plant</td>
<td>elderberry</td>
<td></td>
<td>some</td>
</tr>
<tr>
<td>Plant</td>
<td>wild mint</td>
<td></td>
<td>tons</td>
</tr>
<tr>
<td>Animal</td>
<td>baby mosquito</td>
<td>stream</td>
<td>lots</td>
</tr>
<tr>
<td>Animal</td>
<td>butterfly</td>
<td>path</td>
<td>1</td>
</tr>
<tr>
<td>Plant</td>
<td>wild ginger</td>
<td>woods</td>
<td>100's</td>
</tr>
<tr>
<td>Plant</td>
<td>spring beauty</td>
<td>path edge</td>
<td>some</td>
</tr>
<tr>
<td>Plant</td>
<td>buckeye (tuber)</td>
<td>woods</td>
<td>some</td>
</tr>
<tr>
<td>Plant</td>
<td>Virginia bluebell</td>
<td>path edge</td>
<td>some</td>
</tr>
<tr>
<td>Animal</td>
<td>Canada goose</td>
<td>sky</td>
<td>2</td>
</tr>
</tbody>
</table>

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Wetland Area - In a paragraph, describe the wetland area.

There were many different kinds of trees that were stuck in water about 1 foot high. There were little plants in and around the water and smelled like onions. You could hear frogs.

Write down the animals that you find in the wetland area.

Frogs, bugs, salamanders, toads, mosquitoes

Describe the role(s) the wetland plays in the local ecosystem in the springtime.

provides homes for animals and plants
provides a place for mating

Your group should take a soil sample from the succession area near the trail. Someone in your group will do a chemical analysis of it back at school.

Soil characteristics (done at the park)

Color dark Moisture (moist, dry, medium)
Temperature 19°C How stony is it? not very

Naturalist's Notes

lots of minnows
Choose one (1) of the following three options. For each option focus on both description and empathy (putting yourself in another person’s shoes.) Be sure to vividly describe the area from that person’s point of view, and do so in a language and style appropriate to that character.

The writing should be approximately one page long. Try to use some figurative language. Be as creative as you can!

1. Be Anne Frank or another character that was in hiding. You did escape the Gestapo and have just come out of your hiding place. Big Darby is the first thing you see.

2. Be Adam from I Am the Cheese. You’ve escaped from the asylum and no longer are haunted by your memory. This is the first area you see.

3. You have either been incarcerated or you live in a totally isolated area. (For example, you live in an inner city area or are from a poverty-ridden, 3rd-world country, a country in which you don’t have liberties or freedom.) You come to this place, and it is different from any you’ve seen.
APPENDIX M

MAJOR SCIENCE UNITS AND TOPICS IN THE EIGHTH GRADE
FOR COMPARISON STUDENTS
<table>
<thead>
<tr>
<th>Eighth Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dynamic Earth</strong></td>
</tr>
</tbody>
</table>
| - **Movement of the Earth’s Crust**  
  - Earth’s Changing Surface, The value of the Earth  
  - The Floating Crust.  
  - Plate Tectonics, Plate Tectonics and Life on Earth  
| - **Earthquakes and Volcanoes**  
  - Earthquakes  
  - Formation of a Volcano  
  - Volcano and Earthquake Zones  
| - **Rocks and Minerals**  
  - Uses of Minerals, What is a mineral?  
  - What is a rock?, Rock types  
  - Weathering, soil formation, soil composition, soil to produce food  
| - **Erosion and deposition**  
  - Changing the Earth’s surface, gravity, wind, running water, glaciers, waves.  
| **Exploring Earth’s Weather** |
| - **Weather and Climate**  
  - Heating the Earth, Air Pressure, Moisture in the air  
  - Weather patterns, Predicting the weather  
  - Climate Zones, Changes in Climate  
| **Exploring the Universe** |
| - **Solar System, Earth, and its moon**  
  - The Solar systems evolves, Motions of the planets, Exploring solar system  
  - the Earth in space, the Earth’s moon  
  - the Earth, the moon, and the sun  
  - the space age  
| **Exploring Planet Earth** |
| - **Planet Earth**  
  - Atmosphere, a view of planet earth, development of the atmosphere, layers of the atmosphere  
  - Earth’s oceans  
| **Careers** |
| - Seismologist, Volcanologist, Geophysicist, Gem Cutter, Soil Scientist, Biological Oceanographer, Cartographer, Geologist, Astronomer, Aerospace Engineer  

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APPENDIX N

SCIENCE CURRICULUM OF THE COMPARISON MIDDLE SCHOOL: OBJECTIVES IN THE COURSE FUNDAMENTALS OF SCIENCE
Goal IV: Fundamentals of Science

Program Objective IV-A
Students will investigate the changing nature of the universe through time.
1. Investigate various quantitative change rates and duration of phenomena
2. Trace the development and describe patterns of geologic change.
3. Explain why fossils are found in different sedimentary layers. Demonstrate how the location of fossils in rock layers are used to index other organisms from specific periods.
4. Produce a model to show how fossils were formed.
5. Find examples of weathering. Infer the cause of the weathering (physical or chemical)
6. Explore and explain the rock cycle. Construct a model to show the development of rocks, such as the lithification of sedimentary rocks.
7. Investigate the reversibility of phenomena and events in terms relative to time and space (e.g., changes of phases, collisions, rechargeable batteries).
8. Investigate the scale of historical time (e.g., decades, years, centuries)
9. Explore a variety of media and materials to learn about the plate tectonic theory and its effects on the earth’s crust, for example, continental drift. Develop a model to illustrate their understanding.
10. Compare development of the earth with development of other structures in the universe.
11. Investigate models and theories of change over time including natural selection and speciation, stellar emergence, plate tectonics, and others.
12. Investigate concepts involving large and small time spans such as half-life of radioactive materials, relative life spans of stars and organisms, plate tectonics, and others.
13. Investigate dynamic equilibrium from the perspective of biology, mechanics, chemistry, and others.
14. Investigate the relationship between the rates of energy exchange and the relative energy level of components within systems.

Program Objective IV-B
Students will explore, analyze, and synthesize the physical nature of science.
1. Explore and classify various types of matter. Document physical properties. Develop and explain systems of classification.
2. Distinguish between physical and chemical properties of matter.
3. Develop classification systems for atomic and molecular matter.
4. Develop models to represent chemical structures.
5. Explore motion. Develop an understanding of speed and acceleration and their relation to force and to friction.
6. Explore and describe mechanical waves, and create a model to show the components of the wave (e.g., pitch, crest, trough).
7. Compare and contrast properties of electricity and magnetism.
8. Observe a compass. Explain how it works.
9. Measure and mix dry and liquid materials in prescribed amounts, in various settings, exercising reasonable safety.
10. Develop ideas for alternative forms of energy. Translate ideas into models, and present rationale for use.
11. Compare properties of solids, liquids, and gases.
12. Investigate the periodic table. Develop elementary chemical formulas from the table, and translate them into word equations.
13. Explore physical and chemical changes in matter. Document findings. Compare and contrast physical and chemical changes. Infer reasons for findings.
15. Distinguish between properties (e.g., saturation level, solubility, diffusion, and osmosis) solutions, mixtures, compounds, and elements.
16. Investigate the properties of new materials and compare them with the properties of original materials that new materials replaced.
17. Explore energy transformations in the physical setting and living environment.
18. Demonstrate a knowledge of conservation of energy.
19. Investigate principles that describe the impact of mechanical and electromagnetic waves on various organisms and objects.
20. Investigate resistance to change in natural and technological systems (e.g., dynamic equilibrium, inertia, electrical resistance, and others).
21. Investigate the interactions of objects and organisms in simple technological and natural systems.
22. Explore electricity and circuits.
23. Demonstrate the use of atomic symbols and formulas to represent atomic structure.
25. Explore reactions, such as oxidation-reduction. Monitor and describe the process of a reaction and the result; infer reasons for the result.
26. Identify examples and/or develop models of oxidation-reduction. Develop technologies that could be used to prevent corrosion.
27. Compare the properties and uses of alternating and direct current.
28. Investigate representations of very large scale objects, quantities, and phenomena such as galaxies, Avagadro’s Law, volcanic eruptions, the speed of light, light years, super novas, black holes, atomic ratios, and others.
29. Investigate evidence of relative motion between and among objects such as the Dopper effect, frames of reference, and others.
30. Investigate the influences of groups of objects and organisms on other groups of objects and organisms such as light, sound, electricity, magnetism, wind, predators, pesticides, and others.
31. Investigate macro and micro attributes of objects and organisms.
32. Investigate models of macromolecular structures (e.g., enzymes, crystals, DNA) and the physical and biological implications of these structures.
33. Compare and analyze Newton’s Laws of Motion.
34. Investigate patterns in nature such as heredity, crystalline structures, and populations and resource distributions.
35. Investigate the principles that support predicted motions of objects and functions of organisms.

Program Objective IV-C
Students will explore, analyze, and synthesize the nature of the universe and the earth.
1. Identify the causes of natural disasters and discover factors contributing to their occurrences.
2. Investigate natural resources in the earth’s crust. Learn how living things become natural resources in from of fossil fuels. Classify natural resources as renewable or non-renewable.
3. Investigate various resources cycles in physical and biological systems (e.g., carbon, nitrogen, water).
4. Investigate various impacts of biological and geological activity on the earth.
5. Investigate inferences about large objects, organisms, and systems made from observations of smaller objects, organisms, and systems.
6. Investigate classification systems that are based on attributes that are not readily visible (e.g., electromagnetic radiation, tissues, sounds, minerals, stars, and others).
7. Investigate the limitations of individual components within technological, social, and ecological systems.
8. Identify sources of energy used in the U.S. Trace each source to its origin, and develop a classification system that describes risks and benefits associated with the use of each type of energy.
9. Recognize different properties and characteristics of the earth (e.g., shape, oceans, continents, rocks, and minerals).
10. Demonstrate the processes of erosion and deposition on the earth’s surface.
11. Identify the earth’s hydrologic processes including surface water, water cycles, ground water, and water quality.
12. Investigate the earth’s atmospheric processes (e.g., precipitation and winds).
13. Explore local areas to find examples of the effect of humans on the environment. Document findings. Infer the effect on the environment over short time spans and longer time spans. Develop and present a risk-benefit analysis.
14. Identify a type of energy that is used to heat homes. Monitor energy usage over several weeks. Infer reasons for increases and decreases in energy consumption. Relate energy usage to economics.
15. Explore properties of the earth-moon-sun system. Explain the interdependence and interactions of the components.
16. Investigate the organization within and among the atmosphere, hydrosphere, lithosphere, and celestial sphere.
17. Investigate the limits of size in technological and natural systems.
18. Investigate the renewable and nonrenewable nature of the earth’s resources, and explore various strategies for managing the resources.
19. Qualitatively investigate the geometry and regularity of motion found in interactions in the solar system (e.g., planetary motion, comets, satellites).
20. Investigate the compositions, level of organization, and other attributes of rocks and minerals.
21. Explore a variety of media and other sources to learn about the atmosphere. Prepare an explanation of the implications of pollution in the atmosphere.
22. Quantitatively Investigate the geometry and regularity of motion found in interactions in the solar system, for example, planetary motion, comets, satellites, and others.
23. Explore a variety of media and other sources to learn about the components of the universe. Infer implications of space exploration and colonization for humankind and for the universe.
24. Compare and contrast surface, subsurface, and oceanic land formation processes.
25. Explore a variety of media and other sources to learn about alternative energy technologies. Develop a risk-benefit analysis, including the cost effectiveness of each type of energy.
26. Trace the history of natural resources that were historically used as sources of energy in the U.S. Describe risks and benefits for type of energy source. Infer the risks and benefits of alternative power sources that may be used in place of our natural resources.
27. Explore energy use throughout the world. Compare cultures and their respective energy sources and use. Present conclusions.

Program Objective IV-D
Student will explore, analyze, and synthesize observations from the living environment.
1. Explain the role of a cell in an organism.
2. Develop a system of organization based on structural patterns in a variety of organisms.
3. Describe the interactions and dependence of progressively complex biological systems such as niche, habitat, population, community, ecosystem, and biome.
4. Investigate the effects and interactions of organisms on the physical environment.
5. Identify adaptations of organisms in response to their physical environments.
6. Describe the role of humans in environmental changes.
7. Develop an organizational explanation of traits that living things receive from parents.
8. Investigate the factors that influence the motions of objects and the motions of and within organisms.
9. Explore living organisms and nonliving matter through models and simulations.
10. Prior to collecting and displaying organisms in class, consider and accommodate risks and benefits to organisms and to peers.
11. Build a model to show the functions of the components of basic cell structure. Develop a presentation to explain the interaction of cell components.
12. Investigate several organisms. Develop a graphic display of the structure and function of the organisms.
13. Explore a variety of sources to identify biological compounds needed by living organisms (proteins, fats, carbohydrates, important inorganic compounds, etc.). Infer the consequences of too little or too much of single and/or multiple compounds.
14. Compare reproduction in several different organisms. Explore a variety of sources to identify threats to propagation of organisms.
15. Investigate a classification system for all organisms. Critique and improve the system.
16. Explore the interactions of organisms and the physical environment.
17. Discuss interrelationships between organisms.
18. Investigate models, simulations, multimedia, technologies, and evidence to investigate living and nonliving systems holistically and by component.
19. Investigate the interactions of components of a system within an organism. Collaborate with a peer to compare and contrast systems and interactions of selected organisms.
20. Explain patterns of interaction for a variety of organisms with the environment (e.g., results to stimuli or tropisms).
22. Describe the chemical composition of living organisms.
23. Investigate genetically transferable attributes in living organisms, and suggest strategies to maintain diversity organisms through a variety of reproductive strategies.
APPENDIX O

STUDENTS' PRIMARY INFORMATION SOURCE ON
13 EARTH SYSTEMS AND ENVIRONMENTAL TOPICS

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<table>
<thead>
<tr>
<th>Environmental Topics</th>
<th>Information Sources</th>
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<tr>
<td></td>
<td>S (%)</td>
<td>P (%)</td>
</tr>
<tr>
<td>Acid Rain</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>(88.2)</td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Air Pollution</td>
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</tr>
<tr>
<td>(74.5)</td>
<td>(1)</td>
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<td>(59.8)</td>
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<td>(71.6)</td>
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<tr>
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<td>73</td>
<td>-</td>
</tr>
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<td>(71.6)</td>
<td>(9.8)</td>
<td>(3.9)</td>
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<tr>
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<tr>
<td>(59.8)</td>
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<tr>
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<td>(83.3)</td>
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<tr>
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<td>(34.3)</td>
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<tr>
<td>(77.5)</td>
<td>(1)</td>
<td>(5.9)</td>
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<td>(69.6)</td>
<td>(5.9)</td>
<td>(8.8)</td>
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<tr>
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<td>60</td>
<td>-</td>
</tr>
<tr>
<td>(58.8)</td>
<td>(22.5)</td>
<td>(4.9)</td>
</tr>
</tbody>
</table>

Note: 9 information sources are provided: School (S), Parents (P), TV (T), Internet (I), Newspaper (N), Books (B), Magazines (M), Radio (R), and Don't know (D).

a Percentage includes missing values.

b MS: Missing value

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### Comparison Students

<table>
<thead>
<tr>
<th>Environmental Topics</th>
<th>Information Sources</th>
<th>MS&lt;sup&gt;b&lt;/sup&gt; (%)</th>
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</thead>
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<td></td>
<td>S (%)</td>
<td>P (%)</td>
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<td>Air Pollution</td>
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<td>Water Pollution</td>
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<td>Introduced Species</td>
<td>32 (34.0)</td>
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</table>

**Note.** 9 information sources are provided: School (S), Parents (P), TV (T), Internet (I), Newspaper (N), Books (B), Magazines (M), Radio (R), and Don't know (D).

<sup>a</sup>Percentage includes missing values.

<sup>b</sup>MS: Missing value
LIST OF REFERENCES


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