CHAPTER 1: EVOLUTION OF GLOBAL SCIENCE LITERACY AS A CURRICULUM CONSTRUCT

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1. INTRODUCTION

Science as a major component of school curricula can provide a model of a process for effective communication and decision making across barriers to understanding imposed by differences in culture and language, a fundamental objective of the social studies curriculum construct of global education (Anderson, 1992). The scientific process can provide a model for achieving dialogue among peoples with different languages and from diverse cultures. Science in school curricula can also become a common meeting ground for science teachers and social studies teachers. It provides an avenue of linkage between the curricular areas and an opportunity for interdisciplinary planning and teaching. Together social studies and science teachers can help to ensure that our future leaders and voters will understand our interrelationships with peoples around the world and how our daily activities affect our planet and its resources. This is a fundamental goal of global education. It also lies at the core of Earth Systems Education, discussed in the next section of this chapter, and our efforts to develop a global science literacy rationale and program, the topic of this chapter.

Scientists throughout the world have a single shared subject—Earth and its environment in space—and a common method of study and communication—the procedures and language of science. Scientists start with an accurate description of their observations about Earth processes and materials and then go on to develop logical arguments and interpretations based on those observations of nature. But also, science is a collective endeavor. Examine, for example, the authorship credits for a recent research article in one of the premier American scientific journals, Science, published by the American Association for the Advancement of Science. It is likely that the article will have several authors from different countries or at least from different cultural heritages. In addition, it will cite the work of many others in the same or related fields of science again often from different countries or cultural heritages. These individuals use the mental processes of science and its language to communicate across their disparate cultural experiences and identities in solving problems or studying processes occurring in our Earth systems.

Often a science report will challenge the previous work of those cited. Such a challenge is what keeps science honest even though some of its participants may not be. A scientist's work is replicated, or at least reevaluated, by others and is therefore subject to change and reinterpretation or even outright rejection by the scientific community. As individuals, scientists possess all of the frailties of humans. They make mistakes. They might even misrepresent their data. But if so--they will be found out and corrective action taken. The result of these procedures of science, therefore, is a representation of an Earth process or material that has a high probability of representing that aspect of the real world. Scientists throughout the world, always check their work against the same standard, the observations they make of Earth and its environment in space. Thus, science and its subject--the Earth system--provide an international avenue for communication across the barriers imposed by language and culture. As such the methods of science provide a model of a process for the honest evaluation of social issues and decisions on governmental policies and potential actions that can be less susceptible to bias than are other forms of decision making. It provides a model for an individual's evaluation of information received from a variety of sources and a mechanism for making informed decisions in this ever more complex world.

2. DEVELOPMENT OF EARTH SYSTEMS EDUCATION AS THE SCIENCE FOUNDATION OF GSL

In the past twenty years there have been tremendous advances in the understanding of planet Earth from the application of advanced technology in data gathering by satellites and data processing by supercomputers. As a result, Earth scientists have reinterpreted the relationships between the various subdisciplines and their mode of inquiry. These changes are documented in the "Bretherton Report," developed by a committee of scientists representing various American government agencies with Earth science research mandates. The committee was chaired by Francis Bretherton, a meteorologist at the University of Wisconsin (Earth System Sciences Committee, 1988). This reconceptualization of the process and goals for study of planet Earth was called 'Earth System Science'.

We believe that this report establishes a basis from within the science establishment for conceptually organizing science curricula. Earth system science has now become a model for much of the geoscience research carried on in the USA, not only by government agencies, but by academic institutions and industry as well. Earth system science, instead of the discipline oriented approach to the study of the atmosphere, biosphere, hydrosphere, lithosphere, the solar system and the universe, takes an interdisciplinary or conceptual approach. Physicists, chemists, biologists, geologists--scientists from many different disciplines including the social sciences--work cooperatively applying their special knowledge, skills, and methodology to understand how each of the Earth systems work, how they interact, and how humans affect those systems.

Earth processes (taken to include those operating within the Earth system, the solar system and the universe at large) to be the subject of current and future
research were divided by the committee into two time scales. One deals with relatively short term processes such as those of weather, climate change, and nutrient cycles. These are the processes potentially influenced by human behavior and occur in relatively short time frames from seconds to hundreds of years. The other time scale includes long term processes, such as plate tectonics and the evolution of life operating over thousands to millions of years. The short-term processes are of special concern to the world community because of the disturbances introduced into the Earth systems over the past century by the invention and application of many technologies and by the rapidly growing world population. An understanding of the long-term processes provides a philosophical place for the human presence within the Earth system. Such a background would assist students to more easily comprehend those essential contributions of Copernicus, Galileo, Hutton, Darwin and others that describe our place in the universe.

The committee defined Earth system science with seven statements (ESSC, 1988, p. 21). The first two contrast the traditional Earth science view with that of the new Earth systems science view.

- The two traditional motivations for Earth science are an understanding of the Earth as a planet and the search for practical benefits from such research.
- Earth system science treats the Earth as an integrated system of interacting components, whose study must transcend disciplinary boundaries.

The third points out the reason for this changing focus of the sciences.

- Earth system science has been stimulated by the maturation of the traditional disciplines, a global view of the Earth from space, and the increasing role of human activity in global change.

The next two points explain the two divisions of processes the committee defined.

- On time scales of thousands to millions of years, Earth processes are driven both by internal energy and the external energy of solar radiation.
- On time scales of decades to centuries, Earth processes are dominated by the physical climate system and the biogeochemical cycles, with human activities playing an increasing role in both.

The goal of Earth system science is:

- .... to obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales.

The committee sees the challenge of research to be to:

- .... develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity.
Except for the last point, these statements could be taken to define the nature of a secondary school science curriculum, not just the Earth science curriculum often offered in the ninth grade of American schools.

A second report, dealing only with the solid Earth sciences makes the following recommendation:

**Efforts need to be made to expand Earth science education to all.** Citizens need to understand the Earth system to make responsible decisions about use of its resources, avoidance of natural hazards, and maintenance of the Earth as a habitat. School systems must respond to this need.... (National Research Council, 1993, p. 12)

This report links the need for better understanding among our citizens to the important needs of society in this post-cold war era. As such it provides important support for readressing the importance of including significant content about the Earth system in the nation's science curricula.

3. EARTH SYSTEMS EDUCATION

Earth system science can provide science educators with a conceptual approach to curriculum integration as suggested by Mayer (1995) in proposing the curriculum design effort called Earth Systems Education, not just for a narrowly defined Earth science course, but for the entire secondary school science curriculum. We suggest that such a curriculum could replace the "layer cake" of Earth science, biology, chemistry and physics in the United States and those separate courses taught at various grade levels in other countries. Using the concept of the Earth system and its processes as the organizing framework, basic physical and chemical principles can be learned by the student in a context of intimate importance, the student's habitat. Thus the basic principles of science can be taught more meaningfully and thus be more easily understood and retained. Using such a conceptual approach to the organization of curricula might also avoid one of the fatal elements in past attempts to integrate the science curriculum, the competition between representatives of each of the science disciplines for their 'rightful' place within the curriculum.

When it appeared that science curriculum restructuring efforts in the United States might once again ignore planet Earth, a conference of geoscientists and educators was organized by the American Geological Institute and the National Science Teachers Association with support from the National Science Foundation. It took place in Washington, DC in April 1988. The forty scientists and educators, including many scientists from the agencies responsible for the Bretherton Report, met over a period of five days. Through small group interaction techniques they developed a preliminary framework of four goals and ten concepts from the Earth sciences that they felt every citizen should understand (Mayer and Armstrong, 1990). Through the work of the conference participants and subsequent discussions with teachers and Earth science educators at regional and national meetings of the National Science Teachers Association, a new focus and philosophy for science curriculum emerged under the label, Earth Systems Education (Mayer, 1991).
In Spring of 1990, the Teacher Enhancement Program of the National Science Foundation awarded a grant to The Ohio State University and the University of Northern Colorado for the preparation of leadership teams in Earth Systems Education--PLESE, the Program for Leadership in Earth Systems Education. The objective of the program was to infuse more content regarding the modern understanding of planet Earth into the nation's K-12 science curricula. In preparation for this program, the PLESE planning committee met in Columbus in May 1990, to develop a conceptual framework which would be used to guide the content and philosophy of the program. Input for their work included the Project 2061 report (AAAS, 1989) and the results of the April 1988, conference. Over a period of five days the committee developed a Framework for Earth Systems Education consisting of seven understandings (see figure 1). These understandings provided a basis for the PLESE teams to construct curriculum guides for their areas of the country and for selection of existing materials for implementing Earth systems education in their areas. The PLESE Planning Committee intentionally arranged the understandings into a sequence to draw attention to the importance of the first two understandings especially since they are seldom if ever given importance in traditional science curricula.

Table 1. Framework For Earth Systems Education

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<tr>
<th>Understanding #1: Earth is unique, a planet of rare beauty and great value.</th>
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<tr>
<td>• The beauty and value of Earth are expressed by and for people through literature and the arts.</td>
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<td>• Human's appreciation of planet Earth is enhanced by a better understanding of its subsystems.</td>
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<td>• Humans manifest their appreciation through their responsible behavior and stewardship of subsystems.</td>
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<th>Understanding #2: Human activities, collective and individual, conscious and inadvertent, affect planet Earth.</th>
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<td>• Earth is vulnerable, and its resources are limited and susceptible to overuse or misuse.</td>
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<td>• Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.</td>
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<td>• When considering the use of natural resources, humans first need to rethink their lifestyles, then reduce consumption, then reuse and recycle.</td>
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<td>• By-products of industrialization pollute the air, land, and water, and the effects may be global as well as near the source.</td>
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<td>• The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.</td>
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<th>Understanding #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.</th>
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<td>• 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.</td>
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<td>• 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.</td>
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<td>• Historical, descriptive, and empirical studies are important methods of learning about Earth.</td>
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Global Science Literacy
Mayer, V.J. (Ed.)
2002, XIV, 242 p., Hardcover