DOCUMENT RESUME

ED 354 153 SE 053 117

TITLE	Earth Systems Education: Origins and Opportunities. Science Education for Global Understanding. Second Edition.
INSTITUTION	Ohio State Univ., Columbus. Research Foundation.; University of Northern Colorado, Greeley.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	92
NOTE	63p.
AVAILABLE FROM	Earth Systems Education Program, The Ohio State University College of Education, 1945 North High Street, Columbus, OH 43210 ($5 plus postage and handling).
PUB TYPE	Collected Works - General (020) -- Guides - Non-Classroom Use (055) - Reports - General (140)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Curriculum Design; Educational Strategies; Elementary Secondary Education; Environmental Education; *Global Approach; Integrated Activities; *Science Course Improvement Projects; *Science Curriculum; *Science Education; *Scientific Literacy; Teaching Methods
IDENTIFIERS	Earth; *Earth Systems Education

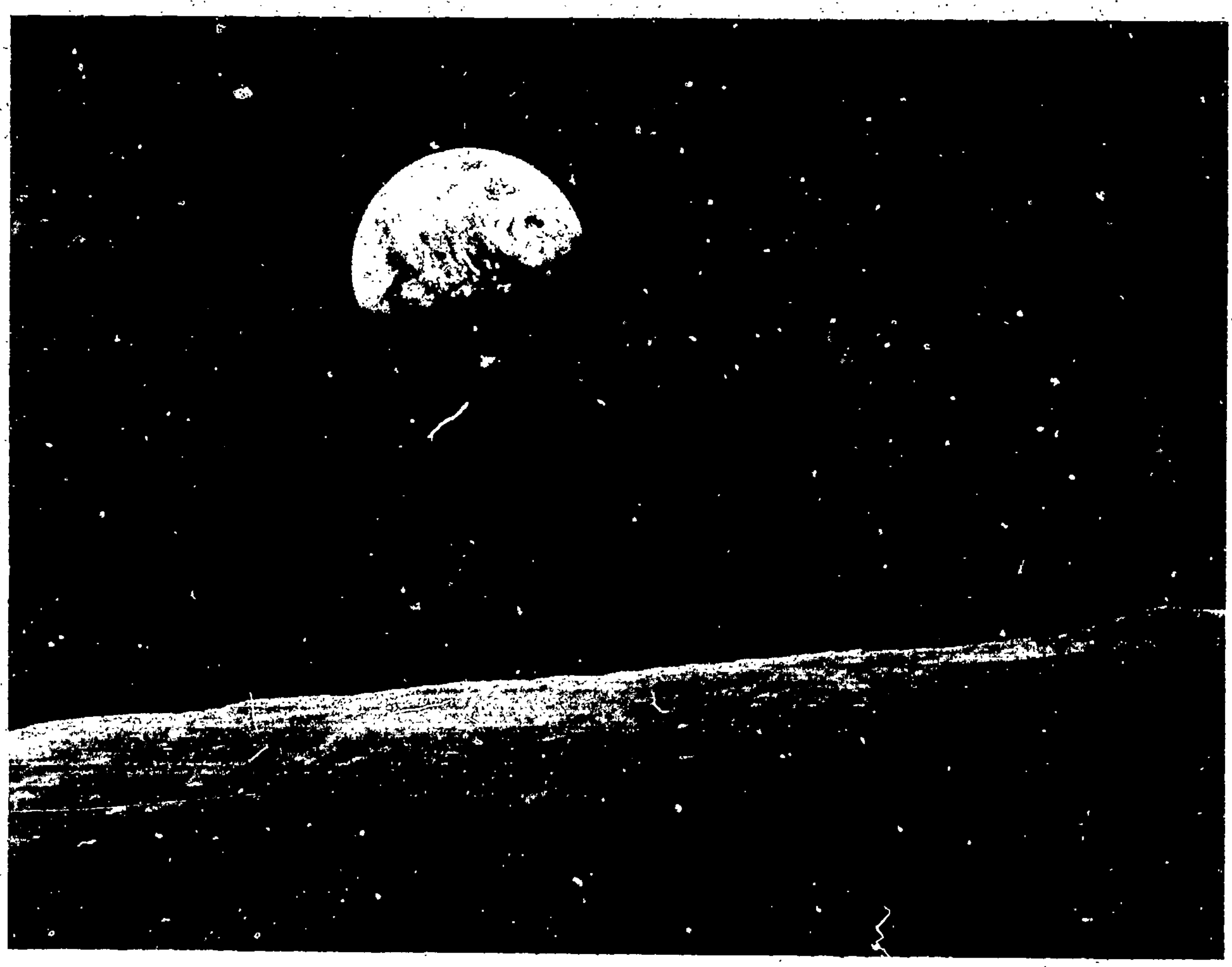
ABSTRACT

This publication introduces and provides a framework for Earth Systems Education (ESE), an effort to establish within U.S. schools more effective programs designed to increase the public's understanding of the Earth system. The publication presents seven "understandings" around which curriculum can be organized and materials selected in a section describing the format of ESE. The rationale for the ESE effort, the need for this approach in the nation's schools, some of the efforts underway and some of the problems that can be foreseen in the implementation of an integrated science curriculum based on ESE are discussed. The following projects in ESE are described: (1) Program for Leadership in ESE (PLESE); (2) Global Change Education; (3) Remote Sensing and On-Line Databases; (4) Biological and Earth Systems Science (BES); (5) Global Change and the Great Lakes; and (6) Earth Systems in the Middle School Curriculum. Comprising half of the document is a collection of journal articles relating to ESE: "Teaching from a Global Point of View"; "Earth Appreciation"; "Earth-Systems Science"; "What Every 17-Year-Old Should Know about Planet Earth: The Report of a Conference of Educators and Geoscientists"; "A Place for EE in the Restructured Science Curriculum"; and "Down to Earth Biology." (MCO)

ED354153

Earth Systems Education: Origins and Opportunities

Science Education for Global Understanding



The Ohio State University and
University of Northern Colorado
with support from
The National Science Foundation

Second Edition 1992

Earth Systems Education: Origins and Opportunities

Science Education for Global Understanding

Contents

Program for Leadership in Earth Systems Education (PLESE)

Contributors

Coordinating Center:

*Victor J. Mayer, Director
Department of Educational Studies
The Ohio State University

*Dan Jax, Associate Director
Bexley Junior High School
Bexley, OH

Joyce Meredith, Staff
The Ohio State University

William C. Steele, Staff
The Ohio State University

Maan Jiang, Staff
The Ohio State University

Eastern Regional Center:

*Rosanne W. Fortner, Director
School of Natural Resources
The Ohio State University

*Ronald Armstrong, Associate Director
South Glens Falls Junior High School
South Glens Falls, NY

*Shirley Brown, Consultant
Clinton Middle School
Columbus, OH

Richard Pontius, Staff
The Ohio State University

Lorien Marshall, Staff
The Ohio State University

Western Regional Center:

*William Hoyt, Director
Department of Earth Science
University of Northern Colorado
Greeley, CO

Ray Tschillard, Associate Director
University School
Department of Earth Science
University of Northern Colorado
Greeley, CO

Project Evaluators:

Iris Weiss
Horizon Research, Inc.
Chapel Hill, NC

Sally Boyd
Horizon Research, Inc.
Chapel Hill, NC

Planning Committee:

* (also on planning committee)

Susan Humphris
Sea Education Association
Woods Hole, MA

K. Lee Shropshire
Department of Earth Science
University of Northern Colorado
Greeley, CO

Lloyd H. Barrow
University of Missouri-Columbia
Columbia, MO

Mildred Graham
Georgia State University
Atlanta, GA

Jane N. Crowder
Issaquah Public Schools
Issaquah, WA

Edwin Shay
Worthington City Schools
Worthington, OH

Gerald Krockover
Professor of Earth and Atmospheric Science
Purdue University
West Lafayette, IN

Aric Korporaal
Los Angeles County Office of Education
Downy, CA

Advisory Committee:

John Carpenter, Chair
Professor of Geology
University of South Carolina
Columbia, SC

Bonnie Brunkhorst
National Science Teachers Association
California State University
San Bernadino, CA

G. Brent Dalrymple
American Geophysical Union
U.S. Geological Survey
Menlo Park, CA

F. James Rutherford
American Association for the Advancement of Science
Washington, DC

Marilyn Suiter
Association for Women Geoscientists
American Geological Institute
Washington, DC

Frank Watt-Ireton
National Earth Science Teachers Association
American Geophysical Union
Washington, DC

Kenneth Wilson
Department of Physics
The Ohio State University

E-An Zen
Geological Society of America
The University of Maryland
College Park, MD

Earth Systems Education ...

an Introduction by Victor J. Mayer

Earth Systems Education (ESE) is an effort to establish within the nation's schools more effective programs designed to increase the public's understanding of the Earth system in which we all live. Opportunities for resource development and the environmental impacts of technical development call for a well-informed public and science and technological communities equipped to make knowledgeable decisions for the public welfare of current and future generations. This requires an understanding of the various Earth systems and how they change through interactions with each other.

The ESE effort has grown out of the foment of science curriculum concerns precipitated by international comparisons of student and adult literacy and the lagging American economic position relative to its foreign competitors. Several large efforts such as Project 2061 and Scope, Sequence, and Coordination are seeking to restructure American science education through various approaches. The ESE effort is consistent with those approaches. However, in the short term, it is simply an effort to infuse modern understandings of the Earth system into the science curriculum K-12. In the long term, however, it has implications for a complete restructuring of the science curriculum with the Earth system providing the focus. Those working on the Earth Systems approach take the position that science is, after all, our effort to understand the planet on which we live and our relationship to its environment in space. Why then, should not the nation's K-12 science curriculum more closely reflect that basic purpose of science, i.e., focus on the Earth system as its subject?

This publication contains several related items. First is the *Framework for Earth Systems Education* that has been developed over several years. It spells out seven understandings around which curriculum can be organized and materials selected. As you read it you will note that it departs significantly from frameworks developed at the national and state levels. First it is short and easily "digested." Second, it doesn't limit itself to the "traditional" science understandings. There is also a place for the aesthetic and creative aspects of science. *Understanding one* focuses on those. The *Framework* also makes a strong statement about personal responsibility for the Earth system in *Understanding two*. The second article "*Earth Systems: Why and How*" goes into some depth on the rationale behind the ESE effort and the need for this approach in the nation's schools. It also summarizes briefly some of the efforts underway and some of the problems that can be foreseen in the implementation of an integrated science curriculum based on Earth Systems Education.

The next section of this publication has brief descriptions of several projects that contribute to the ESE effort. It is followed by several articles that have appeared in *The Science Teacher* that discuss certain aspects of ESE and provide hints and ideas for classroom activities and resources.

We hope that this publication will provide in-depth information for those interested in Earth Systems Education and a beginning for local, state and national development efforts. We feel it has implications for all curriculum restructuring efforts and would encourage those working through Project 2061, Scope, Sequence, and Coordination and other national, state and local level curriculum revisions to consider incorporating aspects of Earth Systems Education into their work. *Earth Systems Education: Origins and Opportunities* has been designed to assist such incorporation.

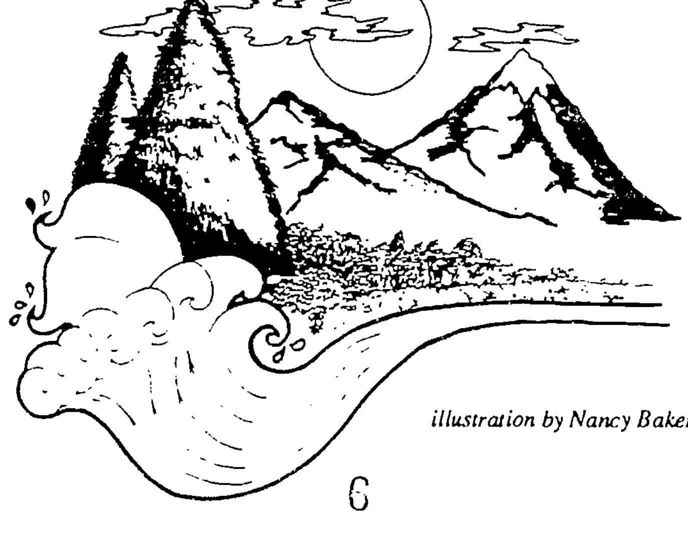
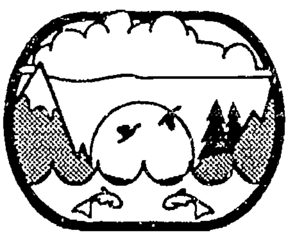


illustration by Nancy Baker-Cazan, 1990 PLESE Participant



Framework for Earth Systems Education

Background

We are in an era of great concern regarding the health of science education in our nation's schools resulting from a variety of national and international studies of American student and adult understanding of basic science concepts. We are also being presented with almost daily reminders of the results of abuse and neglect of our Earth systems such as global warming, ozone depletion and problems of hazardous waste disposal. Our continuing dependence on oil as an energy source has worldwide political repercussions. All are evidence of the general public's ambivalence toward science and a lack of understanding of what science is telling us about the Earth system. Thus there is an immediate need to restructure the science curriculum to ensure that present and future citizens will be scientifically literate—that they will understand the interrelationship between science, technology, and society and the impact that their actions have upon our home, the Earth.

> ***"There is an immediate need to restructure the science curriculum to ensure that present and future citizens will be scientifically literate."***

Responding to the concerns about the level of understanding of science in our schools and society are several on-going curriculum renewal efforts including Project 2061 of the American Association for the Advancement of Science and the Scope, Sequence and Coordination effort of the National Science Teacher's Association (NSTA). Projects such as these have stimulated interest among science teachers and administrators in re-examining what and how we teach science. There is a concern, however, that current efforts may focus too narrowly on the concepts and processes of the traditional science disciplines of biology, chemistry and physics and thus fail to effectively relate science concepts and processes to the Earth system from which they are derived and within which they operate and interact. If that is indeed the case such efforts may contribute to the continued abuse and neglect of the planet Earth systems rather than create the understanding of those systems which could lead to informed political and economic decisions on the wise use of resources of land, air and water.

In September 1985 a meeting of educators and geoscientists, supported by a grant from the National Science Foundation (NSF), met at American Geological Institute (AGI) headdquarters in Alexandria, Virginia. Participants concluded that the top priority for improving Earth systems content in science curricula was the development of a K-12 syllabus. If endorsed by both the science and science education communities, such a syllabus would have a positive impact on textbooks, state and national tests, and curriculum guides.

Science educators and science agency representatives at a series of meetings held in Washington D. C. during the autumn of 1987 concluded that the first step in developing such a syllabus was to hold a conference of eminent geoscientists. A conference was therefore scheduled for April, 1988. Participating scientists were identified from various agencies including the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS) and from several academic institutions. An equal number of educators representing elementary, middle and high schools and local and state school administrations participated in the conference held in Washington and sponsored by AGI and NSTA with support from NSF. Conference participants identified components of our current knowledge of planet Earth that should be included in K-12 curricula. This four and a half day conference focused on identifying those goals and concepts about Planet Earth that every 17-year old should know when completing pre-college education.

Discussions held with various scientists, teachers, and science educators at meetings of the NSTA over the two years following the conference resulted in the evolution of the Earth Systems Education program and a proposal to the NSF for support of The Program for Leadership in Earth

Systems Education (PLESE) which was funded in early 1990. The concepts and goals that resulted from the 1988 conference, along with an analysis of Earth systems concepts from Project 2061's *Science for Americans* were combined and submitted to the Planning Committee of PLESE meeting at The Ohio State University in May, 1990. The committee consists of ten individuals representing science teachers, geoscientists and college science educators. The major objective of this meeting was to develop a framework to be used during the PLESE summer workshops as a basis for developing syllabi and identifying teaching materials. The result of this five day meeting is given in the following *Framework* now being used as the conceptual basis for the PLESE program and other efforts in Earth Systems Education.

The Framework

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 appreciation of planet Earth is enhanced by a better understanding of its subsystems.
- Humans manifest their appreciation of Earth through their responsible behavior and stewardship of its subsystems.

Understanding #2: Human activities, collective and individual, conscious and inadvertent, are seriously impacting planet Earth.

- Planet 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 lifestyle, then reduce consumption, then reuse and recycle.
- Byproducts 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.

Understanding #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

- 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 the interacting subsystems of water, land, ice, air, and life.

- The subsystems are continuously changing through natural processes and cycles.
- The sun is the major source of energy that drives the Earth system.
- Each component of the Earth system has characteristic properties, structure and composition, which may be changed by interactions of subsystems.
- Plate tectonics is a theory that explains how forces and heat cause continual changes within Earth and on its surface.
- Weathering, erosion and deposition continuously reshape the surface of 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.

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 around 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.

System/Subsystem Defined

Any collection of things that have some influence on one another and appear to constitute a unified whole can be thought of as a system (AAAS, p. 123).... Any part of a system may itself be considered as a system - a subsystem - with its own internal parts and interactions (AAAS, p. 124). Thus Earth can be considered a subsystem of the solar system, or the atmosphere as a subsystem of the Earth system.

References

American Association for the Advancement of Science (1989). *Science For All Americans.* Washington, D.C.: AAAS.

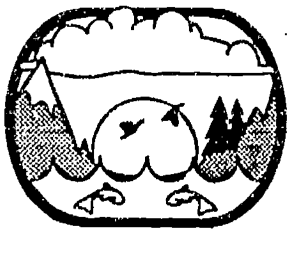
Mayer, Victor J. (1988). *Earth Systems Education: A New Perspective on Planet Earth and the Science Curriculum.* Columbus, OH: The Ohio State University Research Foundation.

Mayer, Victor J. and Armstrong, Ronald E. (1990). What Every 17-year old should know about Planet Earth: A Report of a conference of educators and geoscientists. *Science Education* 74(2): 155-165 (1990).

For more information contact: Program for Leadership in Earth Systems Education, The Ohio State University, 059 Ramseyer Hall, 29 West Woodruff, Columbus, Ohio 43210.

June 5, 1990 Revised June 4, 1991.

illustration by Vicki Vaughan



Earth Systems Education: Why and How

Introduction

The science education community has been confronted with an avalanche of studies and surveys seemingly demonstrating the inadequacy of the nation's science curriculum and how it is delivered. In the face of the veritable storm of concern that has arisen in the wake of these studies several efforts are now underway to radically change the content and organization of the curriculum. They include Project 2061 of the American Association for the Advancement of Science (AAAS) and the Scope, Sequence and Coordination project of the National Science Teachers Association (NSTA). A related effort is the Earth Systems Education program centered at The Ohio State University and the University of Northern Colorado. Its philosophy and approach to science content is consistent with the larger and better known national projects, but differs in significant respects. A major difference is the focus on planet Earth as the connecting subject of the science curriculum. This article describes the rationale for Earth Systems Education, its history and importance, and implications for research and further development that have proceeded from initial implementation efforts.

Science Literacy

The many studies that have focused concern on our science programs are similar in their sources of information and data. They include attempts at measuring science understanding through paper and pencil tests, or in the case of Jon Miller's studies of adult literacy, telephone interviews. The limitations of such information gathering procedures for identifying underlying understandings of science processes and procedures are well documented in the science education literature, especially those dealing with naive theories and misconceptions. Caution should be exercised therefore in the ready acceptance of such data as indicative of the failures of the science curriculum and teaching methods.

Other types of information that have been cited as indicating deficiencies in our educational system include those relating to our apparent declining position in the world economic community. If such a decline can indeed be linked to failures in our educational system then there is some substantial performance based evidence of the system's failings. Again, one must exercise caution in the uncritical acceptance of such measures of educational success. However one views the data cited in support of science education deficiencies there is certainly need for the restructuring of a system that hasn't changed appreciably in the last 100 years.

Earth "Literacy"

Performance based evidence of a nature similar to that demonstrating our economic decline also occurs in another realm; the prevailing economic and political atmosphere which has resulted in the species-threatening deterioration and resource depletion of our Earth system. If our science curriculum successfully prepares citizens to understand science as a rational attempt to learn about our planet and its environs, we should have Earth literate physical scientists, engineers, economists, politicians and industrialists who understand the relationships between the processes that scientists have identified and which engineers have harnessed for economic and defense purposes, and the Earth subsystem from which they were derived. Can this be the case when industrialists, encouraged by their chemists and engineers, until recently recommended the continued use of CFCs and the growing and inefficient use of fossil fuels? If our business and political leaders were Earth literate and understood the relationship between species diversity and the well-being of the biosphere with its implications for future human health and long range economic well-being would we be destroying the rain forests of the Pacific Northwest for short term employment, economic and political benefits? Would our politicians forsake long-range energy policies that would reduce our dependence on oil with its implications for global warming if not world political and "defense" relationships if our political leadership were Earth literate? Not only are we

> ***"...many of our leaders in science, industry, and politics fail to demonstrate by their leadership actions an adequate knowledge of the Earth system."***

becoming a scientifically illiterate country, but even more distressing is that many of our leaders in science, industry and politics fail to demonstrate by their leadership actions an adequate knowledge of the Earth system. They do not seem to be "earth literate."

The performance based type of evidence cited above is supported by the various national and international studies of science achievement and adult scientific literacy. Jon Miller (National Science Board, 1989), for example, found that fully 63% of American adults believe that dinosaurs coexisted with early humans. Responding to another question, 65% were confused as to the cause of day and night. Also fully 54% believed that creationism was at least as scientifically credible for explaining the origin of the human species as evolution. That individual physical scientists can be Earth illiterate is illustrated by an article published in *School Science and Mathematics* entitled "On Darwin's Theory of Evolution," in which the writer, a professor of physics, cites the typical creationist arguments against evolutionary theory. He uses the common creationist technique of citing out-of-context, partial quotes of scientists such as Gould and Eldredge in questioning the theory of evolution (Aviezer, 1988).

No systematic data on Earth literacy have been collected from our political leaders. However, the following excerpt from *Newsweek* (p. 54, April 9, 1990) is revealing. Vice-President Quayle, who is also chairman of the National Space Council, is quoted in response to the question, Why send astronauts to Mars?:

> We have seen pictures where there are canals, we believe, and water. If there's water, that means there's oxygen. If oxygen, that means we can breathe. And therefore, from the information we have right now, Mars clearly offers the best opportunity to see if a man or a woman can be able to survive on that planet.

Our nation's students are equally as unprepared to make decisions regarding Earth processes. Understanding of Earth science concepts in the "six nations study" completed by the Educational Testing Service placed the United States in a last place tie with Ireland with 61% of items answered correctly (Lapointe et al., 1989). The summary of results from the 1984 National Assessment of Educational Progress (NAEP) indicated that whereas declines in other areas of science achievement of 17-year-olds may have been arrested, problems in Earth science knowledge remained:

> Mastery of biology items fell at the same rate as 1977, although the decline is no longer statistically significant. Declines in physical science appear to have leveled off, but Earth science and integrated topics are areas of concern; declines in both clusters are statistically significant (Hueftle, Rakow and Welch, 1983).

Analysis of the most recent NAEP results found nothing to indicate a turn-around had occurred. In fact performance on Earth science questions dropped another 4 or 5 percentage points (Lapointe et al., 1989).

Misrepresentation of the Nature of Science in Curricula

The history of the development of our science establishment is intimately intertwined with perceived needs for military, defense and industrial applications. Funding for research, whether from national treasuries or from industrial pockets, has invariably been tied to the demonstration of short term benefits to the economy, defense, or international status. This has had a major impact on the type of science that has been conducted, not only in the United States but throughout the world. One result has been the emphasis upon a deterministic and reductionist paradigm for science where the isolation and study of specific utilitarian physical or biological processes has been the major goal of investigation.

"The commonly held image of science therefore is that of controlled laboratory experiments conducted by a white balding man wearing a white lab coat."

Although the initial observation and description of phenomena has been fundamental in this process, the primary emphasis is on the study of the phenomena through rigorously controlled experimental techniques. The relatively vast amount of political and financial support available to this phase of science has resulted in the historical and descriptive methodologies being ignored and downgraded. They do not produce the economic and military benefits of the "hard" science approach. After all, of what practical use is an understanding of the evolution of trilobites or of the development of continents and ocean basins?

The commonly held image of science therefore is that of controlled laboratory experiments conducted by a white balding man wearing a white lab coat. Every component of this image is, of course, wrong. The most far reaching impact of scientific investigation on our intellectual and cultural lives has been the result of investigations using historical and descriptive methodologies. They include among others the heliocentric solar system, the expanding universe, organic evolution, deep time, plate tectonics, and most recently, global climate change.

"We have inherited an ancient and irrelevant high school science curriculum."

The science community is now in great flux because of the rapidly emerging understanding of the complexity of Earth systems. The "hard" science approach alone is unable to provide adequate insight into the complex processes of the Earth system, illustrating the severe limitations of reductionist science for studying processes as they occur in the real world. Chaos, a mathematical theory born in the 1960's in large part from Edward Lorenz's attempts to produce more accurate weather forecasting models, has seized the mathematical and science communities with what may become the major scientific revolution of our time (Gleick, 1987). It has the power to change how scientists view not only the world in which we live but how we think about it and how we investigate it.

Chaos theory evolved out of historical-descriptive science and mathematics, and until recently at least, has been resisted by many of those committed to the traditional deterministic and reductionist approaches used in the physical sciences. We see in this development and the growing acceptance of chaos theory the closing of a circle by the "hard" scientists. The linear approaches to science they have championed originally evolved out of the matrix of the natural sciences. Now with their return to the non-linear real world of the natural scientist they bring the mathematical tools that can assist in providing a deeper understanding of our Earth system.

Little of the excitement of science enters our classrooms, and little of its fascinating complexity as illustrated by chaos theory, punctuated equilibrium, earthquake or weather prediction, or the historical development of continents is afforded our brightest students. Instead, the nature of science continues to be inaccurately portrayed in every classroom in our country. Elementary, middle school and high school students learn that unless a person does experiments s/he is not a scientist. Steven Gould commented on this deep seated bias against the historical sciences in his article, *"Evolution and the Triumph of Homology, or Why History Matters:"*

> Historical science is still widely misunderstood, underappreciated, or denigrated. Most children first meet science in their formal education by learning about a powerful mode of reasoning called "the scientific method." Beyond a few platitudes about objectivity and willingness to change one's mind, students learn a restricted stereotype about observation, simplification to tease apart controlling variables, crucial experiment, and prediction with repetition as a test. These classic "billiard ball" modes of simple physical systems grant no uniqueness to time and object—indeed, they remove any special character as a confusing variable—lest repeatability under common conditions be compromised. Thus, when students later confront history, where complex events occur but once in detailed glory, they can only conclude that such a subject must be less than science. And when they approach taxonomic diversity, or phylogenetic history, or biogeography— where experiment and repetition have limited application to systems in toto—they can only conclude that something beneath science, something merely "descriptive," lies before them (Gould, 1986).

The misrepresentation of science that pervades the science curriculum bears bitter fruit in the misunderstanding rampant among the American public of basic concepts such as evolution and the lack of objectivity among the political and business leadership when confronted by issues such as acid rain, global warming or deforestation. An understanding of these issues is dependent upon the historical or descriptive methodology of science. An example of this lack of understanding of the descriptive and historical sciences occurred recently when the President's Chief of Staff began to question the mounting evidence for global warming. John Sununu, trained as an engineer, called into question the quality of that data by classifying scientists working on global change with the pejorative (in his mind) label of "environmentalists," and declared his intent to develop his own global change model, thus, presumably, using the so-called "hard" or linear sciences to "prove" the "environmentalists" wrong.

Science Curriculum Ignores Planet Earth

We have inherited an ancient and irrelevant high school science curriculum. Its influence has permeated into the earlier grades negatively affecting the middle school curriculum, which needs to prepare students for high school, and the elementary school science curriculum, which of course, needs to prepare students for the middle school. Originally established by the Committee of Ten of the National Education Association in 1893 as the college preparatory curriculum in science, the so called "layer cake" of Physical Geography, Biology, Chemistry, and Physics has over the past 100 years changed in only one respect—the effective elimination of the one layer that dealt in some respect holistically with the Earth system—Physical Geography. Despite the curriculum renewal efforts of the 1960's the essence of the science curriculum today is little different than that established by the Committee of Ten in 1893. It is the semblance of what science was in the latter 19th century with a thick, almost impenetrable overlay of modern facts and definitions, not at all appropriate for the economic, global and environmental challenges facing our citizenry today and in the near future.

Is it any wonder therefore that our students and citizens are ignorant of the planet on which they live? Iris Weiss (1987) in her longitudinal studies of science teaching has documented some of the problems in K-12 science education. She found that only 15% of elementary teachers were comfortable with their knowledge of Earth science, while 27% were comfortable in life science knowledge, and 67% in mathematics. This is understandable because the Weiss data also indicate that only 44% had completed one or more college courses in Earth science, while 72% had completed the same in physical science and 86% in life sciences. Most elementary teachers will emphasize those topics they understand. Therefore little is taught in elementary school about the Earth system or our relationships within it and responsibilities toward it.

At the middle school level the situation is somewhat better. About 70% of our children have the opportunity of taking an Earth science course during one of the three junior high school years. Most of the remainder will take general science which normally includes some Earth science content. The quality of the Earth science taught in junior high school comes into question, however, when examining the preparation of the teachers of these courses. Sixty-three percent had three or fewer courses in the Earth sciences compared with the physical sciences, where only 15% had taken three or fewer courses. Of the three science content areas, junior high teachers are by far most poorly prepared in the Earth sciences.

The most serious problem, however, is in the senior high school. According to Weiss' data less than three percent of the nation's senior high school students have the opportunity of taking a course in one of the Earth sciences. This might not be a problem, if the concepts of the Earth sciences were covered in the traditional physical science courses of chemistry and physics. This would seem reasonable since Earth science is often lumped in with the physical sciences. A recent analysis of the most used textbooks in those subjects, however, revealed that *Chemistry*, published by Heath in 1987, had less than 25 pages of a total of 670 devoted in some way to the mention of the Earth system. Chapters 1 and 2 which dealt with water and energy did not contain a single substantive reference to an Earth subsystem. *Physics*, published by Merrill (1986) had only five pages of a total of 549 which dealt somehow with an Earth subsystem. *Conceptual Physics* (Addison Wesley, 1987) did much better, but still only 26 pages of a total of 622 dealt with the Earth system. If the topics are not covered in the textbook, then they are most likely not being covered in the courses in physics and chemistry. Weiss' data (1987) indicates that 93% of all high school science classes use a standard published textbook. The 1986 NAEP data (Horizon Research, Inc., 1989) indicate that in the 11th grade, 70% of the students reported reading the textbook in class at least once a week, with 28% reporting reading the book every day in class. When asked if they ever read articles about science in class, 39% said never, and 26% said less than once a week. The most frequently reported classroom activity was "solving science problems." Seventy-two percent reported doing this at least once a week with 30% reporting doing it every day. This is probably "doing the problems at the end of the chapter." Thus the available data strongly suggest that at the senior high school level, the textbook determines the curriculum, reinforcing the belief that little is done at that level to acquaint our science students with Earth system concepts and processes. Our future

"Our future scientists, politicians, economists and business leaders do not have an opportunity, therefore, to take a science course offered at the level of sophistication appropriate for bright high school students that would inform them about the planet on which they live."

scientists, politicians, economists and business leaders do not have an opportunity, therefore, to take a science course offered at the level of sophistication appropriate for bright high school students that would inform them about the planet on which they live.

Earth Systems Education: A Movement Toward Solution

Since the curriculum revisions of the late 1960's there have been tremendous advances in the understanding of planet Earth from the application of high technology in data gathering by satellites and data processing by supercomputers. As a result, Earth scientists are in the process of reinterpreting 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 government agencies with Earth science research mandates (Earth System Sciences Committee, 1988). This reconceptualization of the process and goals for study of planet Earth has been termed Earth System Science. It provides a conceptual basis for rethinking, not only what should be taught in traditional Earth science courses, but the fabric and organization of the total K-12 science curriculum as well.

The Earth System is a constantly changing entity. Changes occur on two time scales. One set occurs on a scale of millions of years and is illustrated by processes such as plate tectonics and organic evolution. The other occurs on the time scale of decades and centuries and is illustrated by global warming and acid rain. These latter changes are dramatically influenced by the world's human population, an ever more influential component of the biosphere. An understanding of these short term global changes is essential for the health of future generations of humans and of the planet as a whole. Therefore there is a powerful case for making the Earth system a central organizing theme for future K-12 science curriculum development. There is another reason as well. Science, after all, is fundamentally our attempt to understand our habitat and how we came to be a part of it; in other words, our attempt to understand our Earth system. Why shouldn't the science curriculum therefore be organized around the subject of science, the Earth system?

"Why shouldn't the science curriculum therefore be organized around the subject of science, the Earth system?"

Project 2061 is the major attempt thus far in laying the basis for a reconceptualization of the content of the K-12 science curriculum. Its report of Phase I (AAAS, 1989) has heavily influenced the recently completed *California Framework* (Science Curriculum Framework and Criteria Committee, 1990) which is being considered as a possible model of science curriculum by over 20 state departments of education. Project 2061 has also been adopted by the NSTA's Scope, Sequence, and Coordination effort aimed at restructuring the nation's science curriculum. Phase I of Project 2061 was being developed about the time of the publication of the Bretherton report. None of the scientists working on that report were involved in Project 2061. Little of their thinking about the nature of science and the planet that is its most important subject is contained in *Science for All Americans* nor, consequently, the *California Framework*. In the minds of many, this failure to include a central role for planet Earth is a serious omission from documents that may very well determine the future shape and content of science curriculum in this country.

"...this failure to include a central role for planet Earth is a serious omission from documents that may very well determine the future shape and content of science curriculum in this country."

When it became clear that curriculum restructuring efforts might again ignore planet Earth and focus on the deterministic and reductionist model of science, a conference of geoscientists and educators was organized and took place in Washington, DC, during April, 1988. The forty scientists and educators, including many scientists from the agencies contributing to 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). The content of this framework was considered by the Project 2061 staff in the development of their final report. Through the work of the conference participants and subsequent discussions with teachers and Earth science educators at regional and national meetings of the NSTA, a new focus and philosophy for science curriculum has emerged called Earth Systems Education.

In Spring of 1990, the Teacher Enhancement Program of the National Science Foundation awarded a grant to The Ohio State University for the preparation of leadership teams in Earth Systems Education—PLESE, the Program for Leadership in Earth Systems Education. The objective of the program is to infuse more content regarding the modern understanding of planet Earth into the nation's K-12 science curricula. Over the four years of the grant some 60 teams, at least one from each of the 50 states, will be prepared in the philosophy of the program, gather curriculum resources, and learn to organize and lead workshops. They will infuse Earth systems concepts into their own curriculum and assist other teachers K-12 in their states to do likewise.

"The objective of the program is 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 comprised of ten teachers, curriculum specialists and geoscientists, met in Columbus in May, 1990, to develop a conceptual framework. Preliminary work included the analysis of the Project 2061 report for content relating to Earth systems. This analysis combined with the results of the April, 1988, conference was submitted to the committee. Over a period of five days the committee developed a *Framework for Earth Systems Education* consisting of seven understandings (see p. 7). These understandings provide a basis for the PLESE teams to construct a curriculum guide for their areas of the country and for selection of existing materials for implementing Earth systems education in their areas. Once prepared, teams conduct Earth Systems Education workshops in their states and locales.

The Earth Systems Education Framework also has implications for the nation's science curriculum. It departs significantly from Project 2061 and the *California Framework* in its rationale and its focus. The first understanding emphasizes the aesthetic values of planet Earth as interpreted in art, music and literature. It stresses the creativity in the human spirit and how that creativity has perceived and represented the planet on which we live; a creativity that is also essential to the proper conduct of science. By focusing on students' feelings toward the Earth systems, the way in which they experience and interpret them, students are drawn into a systematic study of their planet, i.e. science. By bringing students' attitudes and feelings into the science classroom, science becomes more fully and more accurately a human endeavor, one that involves the total human being in the study of planet Earth and its surroundings. Students are able to draw upon a broad range of talents and interests; both right brain as well as left.

The PLESE Planning Committee intentionally arranged the understandings into a sequence realizing that when numbers are applied priorities are implied. The first two understandings are considered crucial to those which follow and they depart most dramatically from current science curriculum recommendations. By taking the lead in the list attention will be drawn to them. Learning aesthetic appreciation of the planet, the first understanding of the framework, through a variety of techniques and creative activities leads the student naturally into a concern for the proper stewardship of its resources; the second understanding of the framework. 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; the substance of the next four understandings. The last understanding deals with careers and avocations in science bringing the focus once again back to the immediate concerns and interests of the student.

Integrating the Science Curriculum

There seems to be strong movement toward reducing the emphasis upon the distinctions between the science disciplines in the ongoing science curriculum renewal effort. This is clearly the goal of Project 2061 recommendations which are most easily interpreted as a call for an integrated science curriculum. It is also a reasonable extension of the philosophy of the NSTA's Scope Sequence and Coordination projects. Integrating the science curriculum has certainly been a long term goal of the science education community. Attempts such as the Unified Science movement during the 1960's and early 70's have all but vanished as the teachers involved in the original development and implementation efforts moved on to other efforts or retired. Even the attempts of publishers to produce "integrated" elementary science curricula have ended up with simply units of Earth science, biology, and physical science comprising the typical textbook.

What all of the attempts to integrate the science curriculum in the past have lacked was a conceptual focus.

The logical focus for a new integration effort is the Earth system. In essence, science is a study of planet Earth; our attempt at understanding how we got here and how our habitat works. What could be more natural than developing a K-12 science curriculum using the subject of all science

"Integrating the science curriculum has certainly been a long term goal of the science education community."

investigations—planet Earth—as the unifying theme? Any physical, chemical, or biological process that citizens must understand to be scientifically literate can and should be taught in the context from which the particular process was taken for examination: its Earth subsystem. That is the major implication for Earth Systems Education and its impact on the nation's science curriculum reform efforts.

Earth Systems Implementation Efforts

Several projects are underway to test aspects of Earth Systems Education. The major one is the PLESE program which is working with K-12 teams of teachers from each of the 50 states. Through a three-week long summer workshop the three- member teams develop a syllabus based upon the Earth Systems Framework. To do this, each state team selects a topic within one of the Earth subsystems. The teams then reassemble into grade level teams and develop a set of questions for each of the seven understandings that are appropriate for students at their grade level. They do this with reference to a scope and sequence grid having three dimensions—attitude, science methodology, and locale. Each dimension takes into account the appropriate developmental level of the student. Once the questions are identified for each of the grade levels, the teams reassemble

"The logical focus for a new integration effort is the Earth system."

into state K-12 teams and refine and modify the questions to assure articulation between grade levels. Then the second phase begins: identifying from existing resources the activities, audio-visual resources, student readings, and teacher resources that can be used to address each of the questions on the evolving syllabus. What results is a K-12 resource guide for each of the Earth subsystems. Eventually, these will be edited and integrated into a single Earth Systems Syllabus, the final step in the three year-long project. The immediate purpose of the syllabus development is to provide teachers with a resource of ideas for infusing Earth systems concepts throughout the existing K-12 curriculum.

A second project testing aspects of the Earth Systems Education thrust is the development and implementation of an integrated Biological and Earth Systems (BES) science sequence for a central Ohio high school to replace the traditional Earth science course at ninth grade and biology for tenth grade students. The sequence, based on the Earth Systems Framework and philosophy, is organized around basic issues concerned with the Earth system, such as global climate change and deforestation. The program incorporates collaborative learning and problem solving techniques as major instructional strategies. Current technology is also integrated into the courses including the use of on-line and CD-ROM data bases for accessing current scientific data for use in course laboratory instruction. A whole series of issues has arisen around the implementation of this course that needs to be looked at through a rigorous research agenda.

Issues in the Development and Implementation of Earth Systems Education

There are several sets of issues that will affect the development and implementation of Earth Systems Education in the nation's schools. The first relates to the nature of the content and what students know about Earth systems concepts. The second relates to the implementation of any new curriculum into the senior high school, especially one that seeks to integrate the sciences.

An important rationale for including aesthetic appreciation about planet Earth as the first understanding of the Framework is that such a focus would stimulate greater interest among students in studying their habitat. Will a focus on aesthetics indeed facilitate and improve learning about Earth systems? How can a student's feelings about Earth and Earth processes facilitate rather than block the development of understanding of Earth processes? Can science teachers effectively integrate topics from art, literature and music into their science curricula? What mechanisms can be developed to coordinate instruction between humanities and the science curricula of schools?

How can the historical and descriptive methodology of science be effectively taught? Perhaps one of the reasons it is not a more substantive part of the science curriculum is that by its nature the thought processes involved are more abstract and complex than those used in experimental science. Variables cannot be isolated, therefore there has to be a constant and concurrent consideration of all variables in synthesizing and analyzing information. It is difficult for students to collect the types of data that are used in historical and descriptive studies. How can we engage young students substantively therefore in a "minds-on" study of Earth systems?

Most "hands-on" science curricula use activities in which students collect data from simplified laboratory experiments and try to approximate how a scientist would analyze and extrapolate from that data. At best such activities are simulations of what a scientist does. At worst they may misrepresent science and lead to a lack of understanding of the nature of science. With the advent of computer and CD-ROM technology, data banks are now being made available to students that provide real data about the Earth system. There is now the potential for students to manipulate the same data used by scientists with the analysis techniques also used by scientists. Students can study the migration of whales and other species; predict the movement and effect of weather systems; study the distribution of phytoplankton in the oceans. This potential needs to be developed for the science classroom. Once developed such activities need to be studied for their value in improving student understanding of science.

"With the advent of computer and CD-ROM technology, data banks are now being made available to students that provide real data about the Earth system."

Understanding processes in the Earth system requires some feeling for large quantities and a sense for the immense stretches of deep time. How much is a million, whether it is years, miles, or tons? Techniques need to be developed and evaluated that lead to an understanding of such large numbers. Little is done now in schools to establish such understanding. Some teachers have their students count dots printed on sheets of paper, posting them on the walls of the classroom. By the time a million is reached they cover the classroom walls. Are such techniques effective? Are there others that could be used? What is the linkage between comprehension of large numbers and understanding of theories such as evolution and plate tectonics which depend upon long periods of time, or understanding our place in the solar system or galaxy which involve great distances?

One of the major thrusts in science education research is the identification of and strategies for overcoming naive theories of natural processes held by students (Linn, 1987). Most of the effort to date has been in studying basic physical science concepts, such as mass, acceleration and light, isolated from their Earth systems. Several researchers have looked at astronomical concepts such as seasons, Earth's shape and the moon's shape. (Sneider and Pulos, 1982; Treagust and Smith, 1987; Brewer, Hendrich and Vosniadou, 1988; Vosniadou and Brewer, 1987; Vosniadou, 1987; Nussbaum and Novak, 1976; Nussbaum, 1979; Klein, 1982; Mali and Howe, 1979; Sadler, 1987; Schoon, 1989). Few have looked at processes and how they operate within an Earth system except for several studies of weather concepts (Piaget, 1972; Zarour, 1976; Bar, 1983, 1987, 1989; Stepans and Kuehn, 1988).

"Will students living in the shadow of a mountain range have naive theories concerning how mountains are formed?"

Very little has been done to identify misconceptions of processes working within the lithosphere or hydrosphere. For concepts about our Earth system to function effectively as a focus and structure for the science curriculum, there needs to be a major sustained effort at identifying such naive theories about the Earth systems. There are some intriguing possible variations from the studies dealing with basic physical processes that result from the local and regional nature of Earth science processes. Will students living in the shadow of a mountain range have naive theories concerning how mountains are formed? Will the naive theories differ with the type of mountains found in the child's locality? Will they have naive theories about severe storms? Will such ideas differ among children living along the coast where hurricanes occur and those living inland in areas frequented by tornadoes? What strategies are effective in changing naive theories of Earth system processes?

There are a number of factors that affect the implementation of any thoroughly new science curriculum, especially at the high school level. One of the problems associated with the implementation of the BES curriculum has related to the Advanced Placement (AP) courses. Where colleges and universities used to have an indirect influence on the content and nature of the high school curriculum, that influence has become direct and immediate through the spread of Advanced Placement credit. Parents become concerned that their children will not be able to take as many

AP courses if an integrated curriculum, such as the BES mentioned above, is implemented. In addition there is concern that the new curriculum will not provide the background necessary for successful performance in the AP science courses. As more and more school districts implement AP science courses in their attempt to provide "more rigorous" science offerings their influence in dictating the nature of the science curriculum will become pervasive. Yet there is no body of research data on the effects of AP courses. Do they facilitate students' entry to university preparatory programs for science careers? Do AP students do as well in their first college courses in the particular science discipline as those who have not substituted AP credit for the introductory course? If AP courses are to have such pervasive influence on the nature of science taught in our high schools we must have answers to questions such as these.

In an integrated curriculum, how is the talented science student encouraged? High schools are beginning to use versions of cooperative teaching methods. Can they be defined so that they are effective in stimulating and encouraging the talented student? The BES curriculum is using collaborative learning approaches and a special elective honors designation that integrates honors work within the heterogeneous classes. How can such an approach effectively stimulate interest without seeming to be extra work or set the honors students apart from the rest of the class in their own attitudes and those of the other students?

An ever growing deterrent to curriculum innovation is the effect of standardized testing. In an effort to upgrade education, most states are implementing some form of state level testing of students. This in addition to the ever pervasive SATs and other standardized testing programs discourages efforts to substantially reduce the traditional emphasis upon facts and definitions in the science curriculum. In fact it has added to the problem. This negative impact of testing on science programs is well documented in the literature. What is the impact of testing on curriculum innovation? Can tests be developed that are able to assess understanding of broad concepts and problem solving abilities? Despite a great deal of concern and emphasis on these questions over the past decade, little of substance has emerged to guide test development or use.

A variety of other questions have been with us over the years but they become especially important if we are indeed to substantially improve the content of the science curriculum. What is an effective scheduling for science courses? The prevailing pattern today is five 45 to 50 minute periods per week. Should this pattern be changed? If so, how? How can we reduce teacher loads? Most of our foreign competitors, those we are being compared with in the international studies of science education, teach 15 classes per week rather than the 25 or more taught by American high school teachers. If we are indeed serious about fundamentally restructuring the science curriculum, teachers must have time to cooperatively update curriculum and teaching approaches. They do not have that time now. No wonder they simply take the next chapter in the text and use that to guide instruction.

"An ever growing deterrent to curriculum innovation is the effect of standardized testing."

Why has it been so difficult to sustain integrated science curricula implemented in our schools? One of the major problems is the science background of our teachers. NSTA certification requirements essentially include a major in one of the disciplines, biology for biology teachers, chemistry or physics for physical science teachers. In most universities the courses included for the teaching major are the same as those for the major in the discipline. Thus teachers become biologists or chemists or physicists. They do not perceive science as a single discipline. When implementing curriculum in the secondary schools they retain a loyalty to their discipline. They don't feel comfortable teaching concepts they consider to be outside their particular discipline. This is no doubt one of the reasons that so little from Earth systems is taught in chemistry or physics courses. For the new science curriculum restructuring efforts to succeed we will have to restructure the science required in the preparation of science teachers.

"For the new science curriculum restructuring efforts to succeed we will have to restructure the science required in the preparation of science teachers."

Efforts need to be directed to the development of a unified set of courses at the university level that would be the common ground for the preparation of high school science teachers in the discipline of science. In such courses, the Earth system will need to be an integral part, if not the central theme. To do this, university science faculties will need to rethink their discipline's role in the total fabric of science and the contributions it can make to an integrated science course sequence that will need to constitute the core of the science taken by pre-service teachers. To accommodate these changes in teacher preparation programs certification requirements for science teachers will have to be changed. Careful thought should be given to the development of certification standards for a single science program that will accommodate all secondary school science teachers and will reinforce the trend toward the teaching of integrated science.

Finally, the issue that underlies all others is how to make available a sufficient resource base to solve the various problems in science education and education generally. We as a nation currently rank 10th out of 15 industrialized nations in the percent of Gross National Product we spend on education. Yet our political, industrial and business leaders are saying that we already are spending all the money needed for an effective education. How do we refocus the national debate? How can we convince our opinion leaders and our average citizens that additional resources must be made available if we are ever to reach the national objectives for science education stated recently by our governors and the national administration?

Conclusion

The time appears to be ripe for the first total restructuring of the science curriculum since the Committee of Ten established the current high school sequence in the late 1800's. The dramatic changes that have taken place in science and in the understanding of how science is learned, and the evolving demands of technology and the pressures it places on our environment require this restructuring. We must develop a citizenry and a cadre of leaders who are comfortable with science and knowledgeable about the role it plays in understanding our Earth system. They need to understand the applications of science in technology and the role technology plays in our society, in science and in changing our Earth systems. Earth Systems Education offers an effective approach for reaching these objectives. As a first step it provides for infusing planet Earth concepts into all levels of the K-12 science curriculum. For the long run it provides an organizing theme for a K-12 integrated science curriculum that could effectively serve the objectives of scientific literacy and at the same time provide a basis for the recruitment of talent into science and technology careers helping to ensure appropriate economic development consistent with maintaining a quality environment.

References

Aviezer, Nathan, (1988). On Darwin's theory of evolution. *School Science and Mathematics*, Vol 88(7), p. 565-568.

American Association for the Advancement of Science (1989). *Science for All Americans*. Washington, DC: AAAS.

Bar, V. (1989). Children's views about the water cycle. *Science Education*, 73(4):481-500.

Brewer, W.F., Hendrich, D.J., and Vosniadou, S. (1988). A cross cultural study of children's development of cosmological models. In D. Topping, V. Kobsyski, and D. Crowell (Eds.), *Thinking: The Third International Conference*. Hillsdale, N.J.: Erlbaum.

Brush, Stephen G. (1974). Should the history of science be rated X? *Science*, 183: 1164-1172.

Earth System Science Committee, (1988). *Earth System Science*. Washington, DC: National Aeronautics and Space Administration.

Gleick, James (1987). *Chaos: Making a new science*. New York: Penguin Books, Inc.

Gould, Stephen J. (1986). Evolution and the triumph of homology, or why history matters. *American Scientist*, 74: 60-69.

Harms, Norris. C. and Yager, Robert E. (Editors) (1981). *What research says to the science teacher* (Vol. 3: Project Synthesis). Washington, DC: National Science Teachers Association.

Heuftle, Stacey J., Rakow, Steven J., and Welch, Wayne W. (1983). *Images of Science*. Minneapolis, MN: Minnesota Research and Evaluation Center.

Horizon Research, Inc. (1989). *The Science and Mathematics Briefing Book*. Washington, DC: National Science Teachers Association.

Hurd, Paul D. (1986). Perspectives for the reform of science education. *Phi Delta Kappan*, January: 353-358.

Klein, C.A. (1982). Children's concepts of the earth and the sun: A cross culture study. *Science Education*, 65(1):65-107.

Lapointe, A., Mead, N.A., and Phillips, G.W. (1989). *A World of Differences: An International Assessment of Mathematics and Science*. Princeton, NJ: Educational Testing Service.

Linn, Marcia C. (1987). Establishing a research base for science education: Challenges, trends, and recommendations. *Journal of Research in Science Teaching*, 24(3): 191-216.

Mali, G.B. and Howe, A. (1979) Development of Earth and gravity concepts among Nepali children. *Science Education*, 63(5): 685-691.

Mayer, Victor J. and Armstrong, Ronald E. (1990). What every 17-year old should know about Planet Earth: The report of a conference of educators and geoscientists. *Science Education*, 74(2): 155-165.

Mullis, Ina V.S. and Jenkins, Lynn B. (1988). *The Science Report Card.* Princeton, NJ: Educational Testing Service.

National Science Board, (1989). *Science and Engineering Indicators—1989.* Washington, DC: U.S. Government Printing Office, NSF 89-1.

Nussbaum, J. (1979). Children's conceptions of the earth as a cosmic body: A cross age study. *Science Education*, 63(1):83-93.

Nussbaum, J. and Novak, J. (1976). An assessment of children's concepts of the earth utilizing structured interviews. *Science Education*, 60(4):535-550.

Piaget, J. (1972). *The Child's Conception of Physical Causality.* Translated by Marjorie Gabain Totowa, NJ: Littlefield, Adams.

Sadler, P.M. (1987). Misconceptions in astronomy. In Novak, J.D. (Ed.) *Proceedings of the second international seminar on misconceptions and educational strategies in science and mathematics.* vol. III. Cornell University, Ithaca, NY.

Schoon, K.J. (1989). Misconceptions in Earth Science: a cross-age study. Paper presented at the second annual meeting of the National Association for Research in Science Teaching. San Francisco, CA.

Science Curriculum Framework and Criteria Committee (1990). *Science Framework.* Sacramento, CA: California Department of Education.

Sneider, C., and Pulos, S. (1983). Children's cosmographics: Understanding the Earth's shape and gravity. *Science Education*, 67(2):205-221.

Stepans, J. and Kuehn, C. (1987). Children's conceptions of weather. *Science and Children*, 23(1):44-47.

Treagust, D.F. and Smith, C.F. (1989). Secondary students' understanding of gravity and the motion of planets. *School Science and Mathematics*, 89(5):380-391.

Vosniadou, S. (1987). Children's acquisition and reconstructing of science knowledge. Paper presented at the annual meeting of the American Educational Research Association, Washington, D.C. ED 316408.

Vosniadou, S. and Brewer, W. (1987). Theories of knowledge restructuring in development. *Review of Educational Research*, 57(1):51-67.

Weiss, Iris R. (1987). *Report of the 1985-86 National Survey of Science and Mathematics Education.* Research Triangle Park, NC: Research Triangle Institute.

Welch, Wayne W. (1979). Twenty years of science curriculum development: A look backward. In D. Berliner (Ed.), *Review of Research in Education* (Vol. 2, pp. 282-306). Washington, DC: American Educational Research Association.

Zarour, G.I. (1976). Interpretation of natural phenomena by Lebanese school children. *Science Education*, 60(2):277-287.

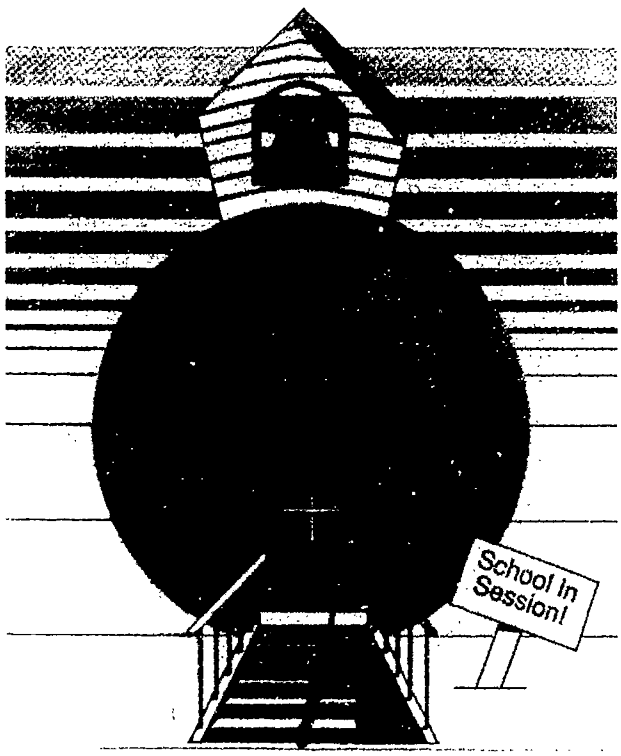


illustration by C. Havel

Projects in Earth Systems Education

- Program for Leadership in Earth Systems Education (PLESE)

- Global Change Education
  Secondary Science Curriculum Modules for Global Change Education: a Progress Report

- Remote Sensing and On-Line Databases
  Using Remote Sensing and On-Line databases for Teaching About Global Change

- Biological and Earth Systems Science (BES)

- Global Change and the Great Lakes
  Global Change Scenarios for the Great Lakes Region
  Ohio Sea Grant

- Earth Systems in the Middle School Science Curriculum

PLESE

Program for Leadership in Earth Systems Education (PLESE)

Funded by a grant from the National Science Foundation, PLESE will prepare over 60 teams of school teachers to become leaders in ***Earth Systems Education*** *over the three-year period 1990-1992.*

The Teams

Project PLESE aims to **reach teachers through teachers**. Participants are selected as **teams** consisting of a high school science teacher, a middle school teacher (usually an earth science teacher), and an upper elementary teacher. The teachers are usually from the same local area but different school districts. All three attend a three-week **summer leadership workshop** in which they prepare to become leaders in **Earth Systems Education.**

A school administrator and a faculty person from a nearby college or university also serve on the teaching team and attend a two-day session during the last week of the workshop.

The Workshops

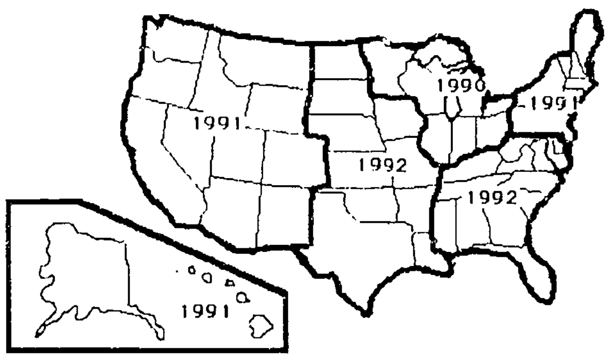
PLESE teaching teams prepare to become leaders in **Earth Systems Education** in the three-week **summer leadership workshop** by

- learning about changes in the Earth Systems from leading scientists involved in **global change research,**
- using a **K-12 Earth Systems Framework** to identify and develop instructional materials about Planet Earth,
- planning to lead **local Earth Systems Education workshops** in the coming school year.

The Locations

The **national coordinating center** and the **eastern program center** for PLESE are located at **The Ohio State University** in Columbus, Ohio. The eastern center will serve teacher teams from the Northeastern states in 1991 and the Southeastern states in 1992.

Located at the **University of Northern Colorado,** the **western program center** will serve the Pacific Coast and Mountain states in 1991 and the Midcontinent states in 1992.



The Benefits

PLESE teacher participants receive a stipend, travel, food and lodging expenses, and graduate credit for successful completion of the program, as well as the satisfaction of presenting at least two local or state workshops in the following school year! They are kept up-to-date through the project newsletter, ***PLESE Note***, and an **electronic bulletin board** system.

College and administrator liaisons receive travel, food, and lodging for attendance at a two-day meeting during the summer workshop.

For more information, contact PLESE at The Ohio State University, 059 Ramseyer Hall, 29 West Woodruff, Columbus, Ohio 43210. Phone (614) 292-7888.

Secondary Science Curriculum Modules For

Global Change Education

A Progress Report

*Funded by the National Science Foundation, the **global change activity project** seeks to develop classroom activities and fact sheets about global change topics for infusion into the high school science curriculum.*

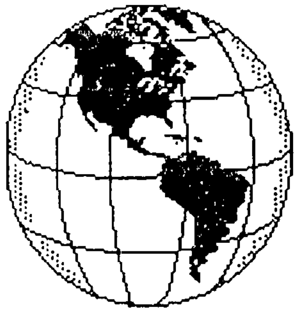
A comprehensive search of curriculum materials designed for high school science classes conducted for the Program for Leadership in Earth Systems Education (PLESE) has demonstrated a lack of teaching materials dealing with the Earth as a system. This is especially true for physics and chemistry classes. The activities and fact sheets being developed by the **global change activity project** are designed to help fill this gap. They include the appropriate science content along with a **focus on the Earth as a system.**

Global change activity topics include, but are not limited to: greenhouse effect and global warming, ozone, deforestation and effects on biodiversity, El Nino, desertification, remote sensing, climate modeling, earthquake prediction, volcanic eruptions, acid rain, and proxy data for global climate change. The impact of technology on the study of the Earth and on the dissemination of information about the Earth is also included.

The global change activity project has included input from science teachers, university educators, and scientists of varied disciplines. They have had the opportunity to interact in a series of seminars held at The Ohio State University beginning in spring, 1989. The information from the scientists and from other original sources helped teachers generate ideas for global change activities appropriate for secondary science classrooms. These ideas and others are being developed into several modules.

Draft copies of activities on global climate warming and climate information contained in ice cores are currently being pilot tested in some central Ohio high schools. These activities will be revised and put into final form for dissemination.

The activities will be accompanied by fact sheets that provide background information on global change topics. The fact sheets can also be used independently of the activities. They will cover topics listed above.



For additional information, contact Victor J. Mayer, or Rosanne W. Fortner, The Ohio State University, Department of Educational Studies, 249 Arps Hall, 1945 N. High St., Columbus, OH 43210

Gl🌐bal Change Technologies

Using Remote Sensing and On-Line Databases for Teaching About Global Change

This project used classroom computers and peripherals to study environmental sciences with original data sources and versatile software. The project was supported by the Ohio Board of Regents with funds from the Dwight D. Eisenhower Math and Science Education Act, from October 1989 through April 1991.

Classroom computers are too often underutilized for the contributions they can make to studies of the earth system. This technology project helped teachers explore the tools available to them and become more aware of the potential of existing hardware and software to open the "real" world of science to students.

The project brought teachers from the Worthington (OH) City Schools and others in central Ohio together with scientists who were using various forms of remote sensing, geographic information systems, proxy data, and on-line databases to study interacting components of the earth system. A global change education seminar was presented by the scientists, followed by sessions to help teachers identify appropriate technologies for their own classrooms.

Supervised curriculum development followed, resulting in fact sheets introducing the technologies and how to apply them, plus some activities demonstrating technology as a tool for understanding global change. These materials are being finalized for distribution. They include information on

- How to access databases on earthquakes, activities of NASA, and environmental information;
- Student activities using Hypercard for classification, data sharing, and charting relationships among earth systems;
- Use of commercial software for unique global change activities and for standard science topics;
- Information on how to obtain and use data from sources such as the Christmas Bird Count, water monitoring programs, CD-ROMs, and climate databases;
- Listing of pertinent government CDs and data sets;
- Descriptions of commercial software adaptable for learning about global change;
- Suggestions for use and interpretation of satellite imagery;
- Examples of how time series data helps to identify trends in global environmental change;
- Sources of "hard copy" data for use in construction of databases or as a substitute for computerized versions.

The project has been closely linked to others in Ohio State University's School of Natural Resources and College of Education: an NSF project to develop global change activities for secondary science, the NSF-supported **Program for Leadership in Earth Systems Education (PLESE)**, and development of an innovative **Biological and Earth Systems** course at Worthington High School. Products of this project are in use by the other projects.

Our hope is that interest among teachers will enable project staff to continue adding to the set of materials for use in teacher education. Comments and suggestions are welcome.

For additional information, contact Rosanne W. Fortner at The Ohio State University, School of Natural Resources, 2021 Coffey Rd., Columbus, OH 43210. Phone (614) 292-9826

Biological and Earth Systems Science (BES)

Worthington (OH) High School

Over the past several years the science teachers of Worthington High School have been involved in ***restructuring*** *their 9th and 10th grade* ***science curriculum.***

Early in 1989, Worthington science teachers began an examination of the various national recommendations for science renewal. They identified a set of curriculum goals as a result of their study. They felt the need to update their 9th and 10th grade curricula. They have now developed a two-year long integrated curriculum using an adaptation of **Earth Systems Education.** The school system has made a major commitment to provide the facilities and equipment (including MacIntosh II cx computers, videodisc equipment, CD-ROM, and access to national data banks). The teachers, with assistance from Ohio State faculty, have secured over $350,000 from federal sources to help in the development and implementation of the course sequence from 1990 through 1993.

The course sequence replaces the traditional Earth science and biology courses. It uses the **Earth Systems Education Framework** as the starting point for identifying content heavily weighted toward the biological subsystem but including content from the other Earth systems as well.

During the first year, critical issues in global science are used as organizing themes for units. The second year focuses on more abstract themes such as evolution and plate tectonics.

The teachers have made a commitment not to use a textbook; instead they have identified a variety of readings from current literature and direct their students to those materials. They have also decreased the use of traditional lecture/discussion and are developing an approach of collaborative learning where students function in teams assuming major responsibility for their own learning.

Supporting the overall restructuring is a heavy use of technology. A variety of data bases are being used directly by students for collection of data and provision of current information. Students use word processing, spreadsheet and data base programs for storing and analyzing information as well as simple data analysis programs. Students also use imagery available on CD-ROM and laser disc as sources of information and data.

The BES curriculum development effort is unique in that it adopts the grassroots approach. The common-sense attitude is taken that science teachers do in fact develop the curriculum which they deliver to students. Why shouldn't they be the developers from the beginning rather than some outside body imposing (in theory) curriculum upon them? Not only do they have the intimate knowledge of their students, but they also have the necessary science background and professional competence to identify and sequence the necessary materials and activities.

The new course sequence is being monitored not only by teachers, but by two advisory committees composed of university professors, educators from other area districts and residents who work in science fields.

The school district administration is providing important support through resources and developing the appropriate public relations. Ohio State University is assisting teachers with "outside" support, integrating their efforts with national developments, and providing access to training and information that they may not be able to access themselves.

For more information contact Roger Pinnicks, Thomas Worthington High School, 300 W. Dublin-Granville Rd., Worthington, OH 43085

Global Change Scenarios for the Great Lakes Region

Because global change issues are often difficult to understand, many people – including important decisionmakers – are hesitant to support global change policy suggestions by the scientific community. Instead, these people take a "wait and see" attitude toward global change which, unfortunately, defeats the purpose of any pro-active suggestions the scientific community may offer.

The Ohio Sea Grant Education Program is currently preparing a series of short publications designed to help people understand how global change may affect the Great Lakes region. By explaining the possible implications of global change for this region of the world, it is hoped that policy makers and individuals will be more inclined to make responsible decisions about global change policy issues.

The publications, called 'scenarios,' describe the prevailing interpretations of the scientific community concerning what may happen to the Great Lakes region in the face of global warming. The scenarios are written in terms the general public can understand and their content is reviewed for accuracy by a panel of experts. The scenarios are between two and four pages in length and include the most recent information available on a variety of subjects, including the potential effects of global change on:

- ***Agriculture:*** How will agriculture in the Great Lakes region be affected?
- ***Airborne Toxins:*** Will global warming affect airborne circulation of toxic substances?
- ***Recreation:*** What could happen to Great Lakes recreation?
- ***Biological Diversity:*** How will food webs be altered as species disappear or expand their numbers?
- ***Estuaries:*** What are the implications for low-water levels in Great Lakes estuaries?
- ***Water Pollution:*** Will lower water levels concentrate pollution or dangerous toxins in nearshore areas?

When completed, the scenarios will be made available to educators and other interested individuals. A limited number of classroom activities illustrating these possibilities will be developed as well.

For additional information, contact Rosanne W. Fortner, The Ohio State University, School of Natural Resources, 2021 Coffey Rd., Columbus, OH 43210. Phone (614) 292-9826

EARTH SYSTEMS IN THE MIDDLE SCHOOL SCIENCE CURRICULUM

Integrating the science curriculum in central Ohio schools

Since science is our attempt to understand the Earth on which we live and Earth processes that influence our daily lives, shouldn't the science curriculum in our schools use planet Earth as the focus for integrating our knowledge of the process and product of science? Since much of science in the past has been an effort to harness Earth processes for the use of its human population, shouldn't the science curriculum consider technology from the point of view of its impact upon Earth systems? These are questions that are guiding the thinking and work of thirty middle school science teachers from the central Ohio area, in a unique program supported by the Dwight D. Eisenhower program of the Ohio Board of Regents.

The school teaching staffs from one of the middle schools in each of the following school districts are involved: **Columbus City Schools, Southwestern City Schools, Bexley City Schools, Whitehall City Schools, Marysville City Schools, the Columbus Catholic Archdiocese Schools, Upper Arlington City Schools** and **Mansfield City Schools**. Teachers meet together for six full-day sessions and for three meetings in their own school on a quarterly basis for the duration of the project. The goals of the meetings are to create and use a regional network of middle school science teacher leaders, to provide background in recent global science developments, to review current educational theory and practice as applied to the middle school and science teaching, to become familiar with new materials and technology for teaching science, and to initiate the process of developing integrated Earth system science middle school curricula for their particular school districts. The meetings use a collaborative working approach where much of the time is spent in school district or grade level teams discussing science topics, analyzing new educational approaches for their relevance and utility, designing curriculum and developing teaching resource collections.

This program is a spin-off from the Program for Leadership in Earth Systems Education, a National Science Foundation supported project that developed the philosophy and rationale for the Earth Systems Education approach. Several of the teachers have participated in the PLESE summer program where they became enthusiastic about the potential for its application to middle school science curriculum restructure. These teachers worked with staff at the Ohio State University to secure funding and to design the middle school program.

Additional information can be obtained from Vic Mayer, Earth Systems Education Program, The Ohio State University, 29 W. Woodruff, Columbus, OH 43210. Phone (614) 292-7888.

Articles Relating to Earth Systems Education

- Teaching from a Global Point of View
  from *The Science Teacher*, January 1990
  Victor J. Mayer

- Earth Appreciation
  from *The Science Teacher*, March 1989
  Victor J. Mayer

- Earth-Systems Science
  from *The Science Teacher*, January 1991
  Victor J. Mayer

- What Every 17-Year Old Should Know About Planet Earth: The Report of a Conference of Educators and Geoscientists
  from *Science Education* 74(2): 155-165 (1990)
  Victor J. Mayer and Ronald E. Armstrong

- A Place for EE in the Restructured Science Curriculum
  from *Confronting Environmental Challenges in a Changing World*, 1991
  Rosanne W. Fortner

- Down to Earth Biology
  from *The American Biology Teacher*, February 1992
  Rosanne W. Fortner

Teaching From a Global Point of View

by Victor J. Mayer

Broadening our perspective as our universe shrinks.

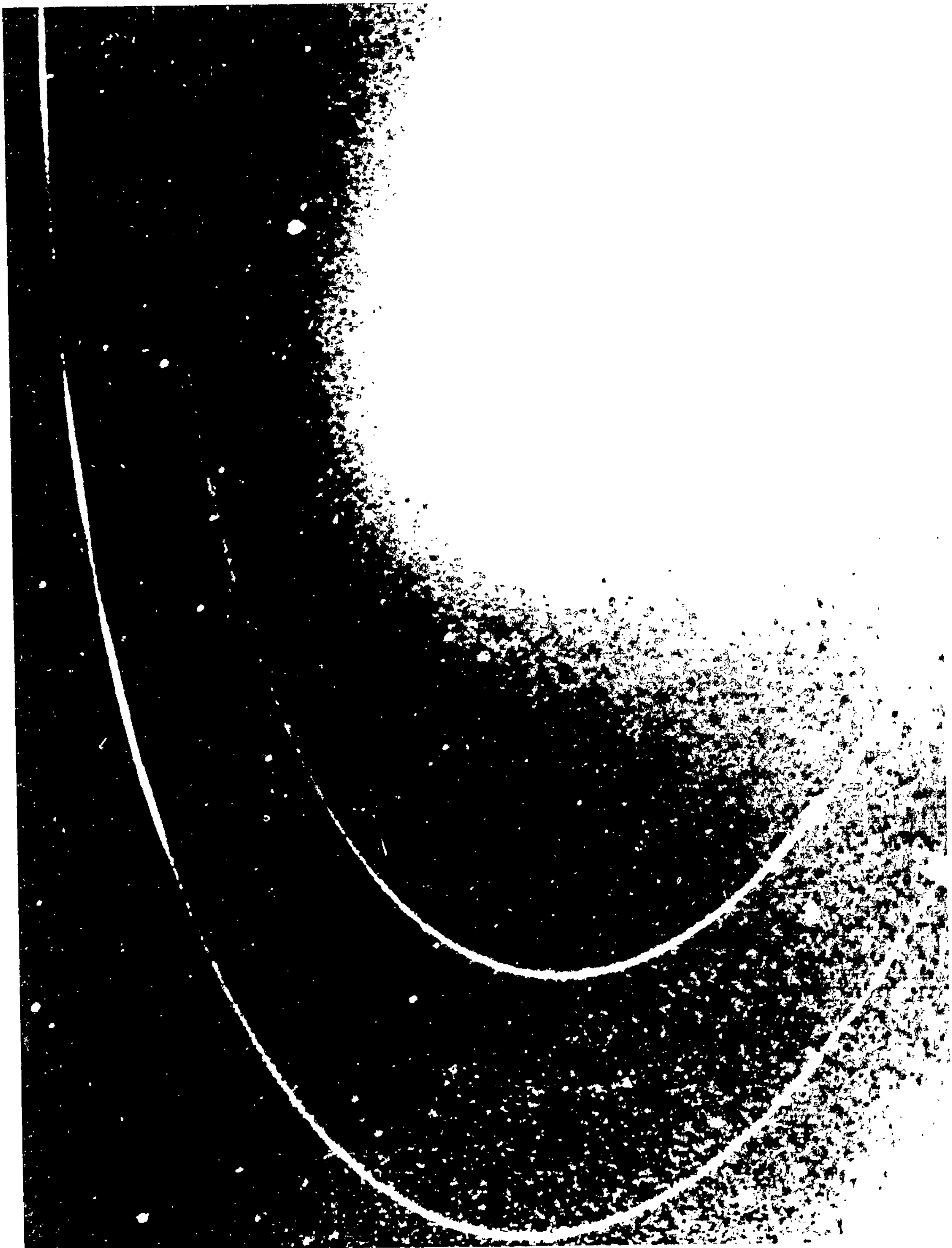
The 1981 launch of the space shuttle Columbia was the capstone of a long series of accomplishments that fundamentally changed our understanding of our habitat—the planet Earth. Our perception of its size had been diminishing since the time of John Glenn's orbiting of the planet, climaxing with the sight of the Earth suspended over the Moon's surface in pictures returned by the lunar expeditions. Our space exploits have provided a spectacular setting in which to consider global education and the role it should assume in science education.

Global education is a movement with a 20 year history founded primarily in social studies education. Global education has been defined as ". . . the knowledge, skills, and attitudes needed to live effectively in a world possessing limited natural resources and characterized by ethnic diversity, cultural pluralism, and increasing interdependence." As such, it incorporates aspects of environmental education as well as international education. Global education has as its central goal the establishment of cross-cultural understanding and a cooperative attitude toward world problems.

Our technical accomplishments make the achievement of such an international understanding extremely important. We will for example, be able to transport minerals from the Moon and asteroids to factories in Earth's orbit, thereby making available an abundant supply of these resources. We also will be able to obtain limitless energy from the Sun, using solar energy collectors placed in orbit by advanced versions of the space shuttle. The economic realizations of such endeavors, however, will require international cooperation.

Our ever-shrinking universe

More important than the material benefits is the expansion of the frontiers of knowledge made possible by such technological achievements. We can now see 8 billion light years into the past; halfway to the beginning of the universe. The Hubble telescope orbiting outside the Earth's atmosphere will permit us to look even further into the origins of the universe. Already we have seen sights in our own solar system that no one had predicted. The Voyager flybys of the outer planets have provided us with views of erupting volcanos on Io, a moon of Jupiter, and an immense storm system on Neptune. The advantages of international cooperation were amply demonstrated by the Soviet and European effort to obtain close-up information during the recent passage of Halley's Comet. Space programs are providing nations with a startling new perception of their place, not only in our world society, but in our solar system and our universe. At the same time, the spectacular failures of our technology, such as the Challenger disaster that took the life of Christa McCauliffe and her fellow astronauts and the Chernobyl accident which spread nuclear debris to countries around the world, remind us of



the limitations of our technology, the fragility of human existence, and of the shared destiny of all nations on our planet.

Science as a model for global education

Our accomplishments and failures are technological. They result from applications of the accumulated principles and facts uncovered by the work of thousands of scientists throughout history. One of the basic problems in achieving an international understanding is the difficulty in establishing an understanding among peoples across the barriers of language and culture. Science can provide a useful model, since scientists of all languages and cultures have a subject of study in common— our Earth— and a process they use to study it.

They start with an accurate description of observations and then logically develop arguments and interpretations based on those observations. Science is a collective endeavor. Scientists will challenge each others' results and attempt to replicate them. As individuals, they possess all the frailties and fallibilities characteristic of the human state. They make mistakes. They may even intentionally falsify data. But science has correcting mechanisms. Mistakes and falsified data will be revealed by the work of others. The result of this process is a product that accurately represents nature in as far as the available evidence allows. Science, therefore, is ethical and honest. It simply seeks the best representation of the natural world. Thus, science is amoral, that is, it seeks neither right nor wrong, only the best explanation. Leaders in government, industry, business, and society select from among the principles and information made available by science. They may use it

Satellite 1989 N1, discovered by Voyager 2 (left). *Triton from 80,000 miles* (right).

Global education should be a thread running through science curriculum.

in ways others may judge as right or wrong, moral or immoral.

The effects of technology

Science provides knowledge that can be used to improve our living standards. Industrial and political leaders make decisions that apply this knowledge as technology. Technology does not have the self-correcting mechanisms that science does and, therefore, lacks its ethical base. Knowledge can be used in different ways—for the long-term benefit of all, for short-term political gain, or for destructive purposes. Even when used for the most beneficial purposes, the technological use of knowledge can be destructive if the long-range results have not been considered. For example, the manner in which our leaders have responded to energy needs reflects their failure to understand the long-range implications of excessive energy consumption. Decisions have been made that maximize the short-term gain or profit from energy use but result in long-range problems. Our exploitation of fossil fuels—including coal, oil, and natural gas—has had lasting detrimental effects upon our environment. Some are readily recognized: the ravaged landscape of strip-mined areas of Ohio and West Virginia and the oil spills from damaged tankers such as the Exxon Valdez. Other effects, though more subtle, are perhaps much more threatening to our survival.

One issue of global concern is the introduction of carbon dioxide into the atmosphere through the burning of fossil fuels and the resulting enhancement of the "Greenhouse Effect." There are alternatives to the use of fossil fuels, such as nuclear energy, solar energy, and conservation. To shift our emphasis to these alternatives, however, requires understanding, commitment, and leadership.

Global education, science, and technology

The scientific approach can provide a

—Photo courtesy of Jet Propulsion Laboratory

model for achieving dialogue among peoples of different languages and divergent cultures. Thus global education should be a thread running through science curriculum. Our future leaders and voters (today's students) must understand our interrelationships with peoples around the world and how our daily activities affect our planet and its resources. If they are to make wise decisions concerning the application of scientific information, students must realize that it can benefit or can damage the lives of all. Our leaders must be prepared to draw on scientific findings not for their own self-interest but for the sake of the common good; in the interests of all the world's people. In many ways, the science teacher can be central to

Victor J. Mayer holds appointments as professor of science education, geology and mineralogy, and natural resources at The Ohio State University, 249 Arps Hall, 1945 N. High St., Columbus, OH 43210.

accomplishing this goal. Therefore, it is important that teachers and curriculum developers understand the goals of global education ar ' how it relates to the science curriculum.

Including global education in science curriculum

How can you incorporate activities that

The investigations draw upon a variety of disciplines in addition to science and social studies.

lead to global understanding into your curriculum which is already overburdened? Teachers working in marine and aquatic education have developed an infusion model that could prove of some help. We have used their model in a series of investigations designed to impart marine and/or aquatic information. These activities are developed around basic topics or concepts already taught in middle school. The investigations draw upon a variety of disciplines in addition to science and social studies. They are short and self-sufficient and thereby easily inserted into existing curricula.

An example of one such investigation, entitled *It's Everyone's Sea: Or Is It?*, explores the interests of different countries in using the sea as a resource. It starts with a map-reading exercise that asks students to identify topographic features of the Atlantic Ocean Basin and to locate major resources – including potential oil reserves on continental shelves, manganese nodule deposits in some of the deep ocean basins, and the major fishing areas. They also examine the position of eight countries relative to seas, ranging from landlocked nations such as Bolivia to island states such as Bermuda.

The second part of the exercise is a simulation of the Law of the Sea Conference. The class is divided into groups representing eight countries. Each delegation presents its positions on resolutions concerning the right to free passage of ships, pollution control, and the allocation of sea resources. In the third part of the investigation, students examine the manner in which international borders are designated and analyze the sources of border conflicts between Canada and the United States. Through this activity, students learn that problems of resource use are not solved merely by the technical application of scientific knowledge. Rather, solutions require informed guidance by political specialists, frequently in an international context.

Preparing teachers

We have used the infusion approach to prepare future teachers in global education. Working with one of our faculty members in social studies education, who is also a national leader in global education, we developed a series of activities and integrated them into topics normally taught during our science methods overview. They include: the nature of science, critical reading skills in science, and the use of simulations. The activities not only provide our students with a global

Students should learn to recognize the global threat posed by LA's smog (above) *and the Amazon's deforestation* (right).

perspective, but also can provide ideas for secondary school science teachers who may be trying to incorporate some of the objectives of global education into their courses. The activities take about five 2-hour long class periods.

The first activity is a review of the nature of science using an analysis of creationism and evolutionary theory as science. It begins with a presentation of the filmstrip *Scientific Methods and Values* (Hawkhill Associates, Inc., 125 E. Gilman St., Madison, WI 53703), and students read the Overton Decision (Rev. Bill McLean vs. Arkansas Board of Education, Opinion of William R. Overton, United States District Judge). The latter is discussed, emphasizing the differences between scientific theory and religious precepts. From this discussion, students develop a set of criteria that allow them to discriminate between scientific and religious ideas.

We also have the students read an article that summarizes creationists' evidence regarding the coexistence of dinosaur and human footprints (Milne, David H., and Steven D. Schafesman. "Dinosaur Tracks, Erosion Marks, and Midnight Chisel Work (But No Human Footprints) In the Cretaceous Limestone of the Paluxy River Beds, Texas." *Journal of Geological Education*. 31:111-123, 1983). Some of the teaching materials developed by the Creation Research Institute of San Diego, Calif., are analyzed using the criteria developed in the discussion. This module helps students achieve a better understanding of science as a reasoning process and as a discipline; two aspects that are essential to an appreciation of the importance of science in global issues.

Students then view an episode of PBS's *NOVA* that focuses on Steven Jay Gould's trip to South Africa. During the program, Gould discusses the development of the concept of human evolution, how scientists allowed their prejudices to affect their interpretation of data, and what influences these interpretations had upon social and economic policies in certain countries. The program and subsequent discussion point out the interdependence of the world's nations and the manner in which science can be used to either cause or alleviate problems.

The unit concludes with a discussion of the role of the science teacher in global education.

A rounded education

Our next section begins with a presentation of the filmstrip "Who Owns the Oceans?," which provides an overview of the various interests that nations have in the sea (Current Affairs Films, PO Box 398, 24 Danbury Rd., Wilton, CT 06897). The first two parts of the activity, *It's Everyone's Sea: Or Is It?*, described earlier in this article, are then used to point out the interdependence of nations.

An environmental section follows with two activities that demonstrate environmental problems shared by several countries. One is a simulation on acid rain that was described in the April 1984 issue of *The Science Teacher* ("The Acid Rain Debate," Bybee, Rodger, Mark Hibbs, and Eric Johnson). The other is a lab activity on the effects of atmospheric carbon dioxide and the Greenhouse Effect taken from the February/March 1986 issue of *Science Activities* ("The "Greenhouse Effect," Andrews, David).

This section concludes with a presentation of information about acid rain developed by two different sources. One is a videotape prepared by an Ohio power company, "Energy and Electricity," (NSTA/Columbus and Southern Ohio Electric Company Honors Workshop for Teachers). The other is a filmstrip set prepared by a Canadian agency, "Acid Rain: The Barriers to a Solution." (McIntyre Visual Publications, Inc., 716 Center St., New York, NY 14092). They take drastically different positions on what science has to say regarding the problems and sources of acid rain. Our students critically analyze each of the programs for emotional loading and factual errors. They also discuss the international implications of acid rain.

The unit concludes with a discussion of the role of the science teacher in global education and the techniques that can be used to integrate it into science teaching. Teachers of all disciplines, especially elementary school teachers, need to recognize the importance of science in the curriculum not simply as science per se, but in how it relates to the social, political, and economic spheres of human endeavor. We must also consider the products of science and how they can be used for the betterment or detriment of our life on Earth. We must see science as a bridge to other cultures and as a basis for communication. A focus on global education can help our students to realize that a sharing of ideas and cooperation among cultures is to the benefit of all. The science teacher can be a key figure in accomplishing this goal. ■

For further reading

Gilliom, M.E., "Global Education and the Social Studies." *Theory Into Practice*, Summer, 1981, p. 170

Note

If you are interested in obtaining materials from "It's Everyone's Sea: Or Is It?" (Mayer, Victor J., and Stephanie Ihle. Columbus: Oceanic Educational Activities for Great Lakes Schools. Ohio Sea Grant Program, 1981, 1987), please contact the author for further information.

Earth Appreciation

by Victor J. Mayer

Reflections of earth science in art.

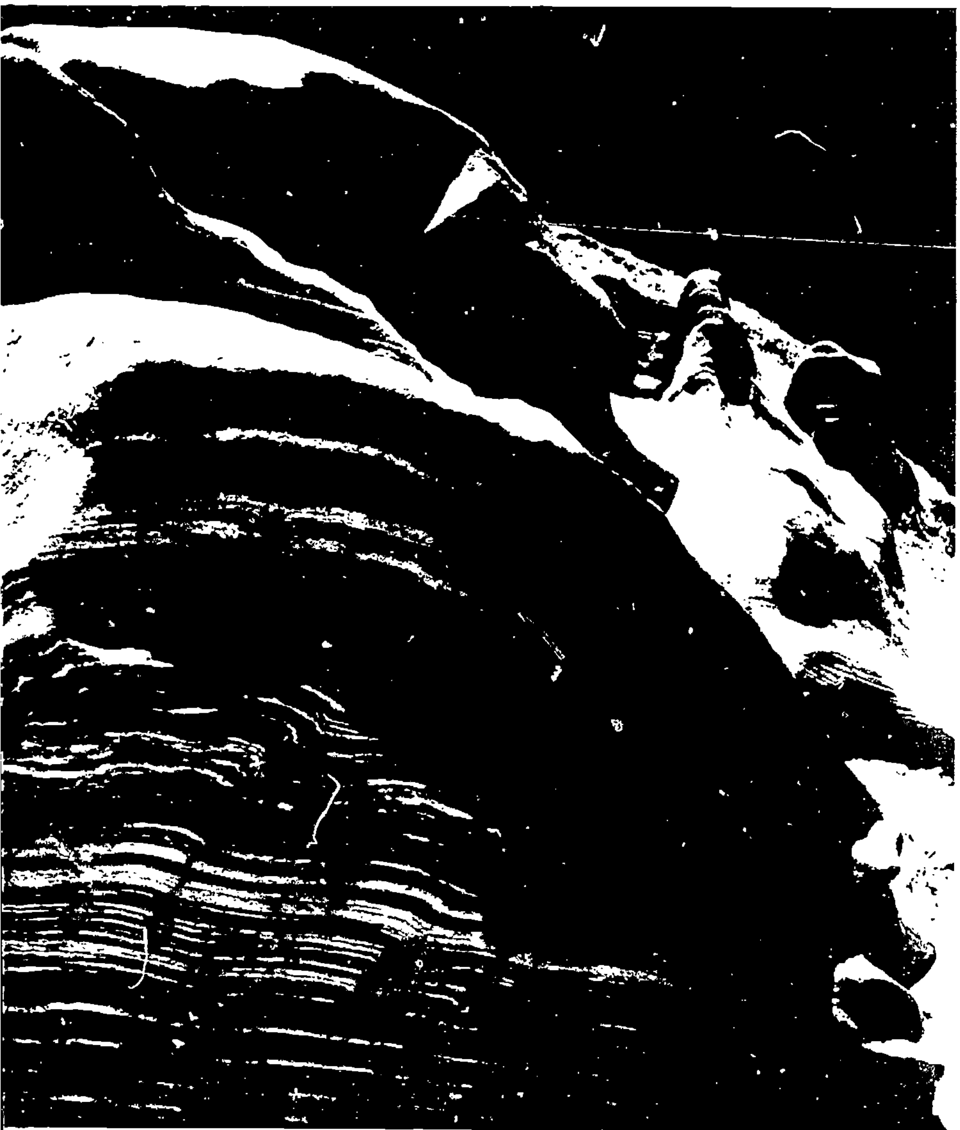
Do you often find it difficult to illustrate a scientific process in a way that will capture the interest of your students? Earth science teachers are fortunate to have help when faced with this problem. They can tap into a variety of sources outside of the science teaching resources that are normally available. They can make the study of earth processes fascinating by appealing to the variety of interests students have in history, art, and literature. Often, just the right information or illustration can be found in one of these fields that can help a certain student or class grasp a certain topic more thoroughly.

A number of years ago, for example, there was a popular movie entitled *[illegible]*. It was an account of the exploration of the Grand Canyon by Major John Wesley Powell during the late 1800s. Powell was a fascinating man and an excellent example of how historical figures can be used to introduce certain areas of earth science.

Powell, an officer during the Civil War, lost his arm during the battle at Shiloh. Despite this handicap, he later became one of our country's most prominent scientists. He founded the Bureau of Ethnology and helped to found the United States Geological Survey. In 1888, he was elected president of the American Association for the Advancement of Science.

Powell was an excellent writer. His exciting account of his travels through the West includes observations of the Grand Canyon and the Colorado River that can be used to teach basic concepts of erosion, sedimentation, stratigraphy, and geologic history. The following is a sample from his journal:

"July 13 — Extensive sand plains extend back from the immediate river valley, as far as we can see, on either side. These naked, drifting sands gleam brilliantly in the midday sun of July. The reflected heat from the glaring surface produces a curious motion of the atmosphere; little currents are generated and the whole seems to be trembling and moving about in many directions, or, failing to see that the movement is in the atmosphere, it gives the impression of an unstable land. Plains, and hills, and cliffs, and distant mountains seem vaguely to be floating about in a trembling, wave rocked sea, and patches of landscape will seem to float away, and be lost,



Adams's [illegible] of light, shadow and angle has converted a rock outcrop into an artistic image (left). On [illegible] [illegible] out of the manner in which particles forming sandstone were deposited. Using such images to teach geological concepts such as [illegible] provides not only knowledge of the concept but also an esthetic feeling for a portion of the Earth.

and then reappear. (Powell, 1957, p. 40)

This excerpt is typical of Powell's writing. What is impressive is his ability to put action and excitement into words and also his very vivid descriptions of natural phenomena, such as air currents generated by the heated sand surface. How much more interesting is this writing than that which we normally find in science textbooks.

A fascinating series of events from our history that can be used to illustrate not only the nature of earth processes but also how such processes have been used to mislead people are related by Allan Eckert's book *The Frontiersman* (1967). He tells of the great Indian leader Tecumseh, who if the historical records are correct, was born in a year that a comet visited our solar system. According to Indian legend, this gave him great power.

During the early 1800s, he was attempting to rally the Indian tribes for an attempt to reclaim their lands from the Americans. During his travels to raise support, he told his allies to expect two signs that would confirm his power and signal them to join him in battle. On the night of November 16, 1811, a meteorite flashed across the Midwestern sky. Eckerts' allies took this as the first sign. Then, 30 days later, an even more powerful event occurred. Eckert provides a fascinating description:

"In the south of Canada, in the villages of the Iroquois, Ottawa, Chippewa and Huron, it came as a deep terrifying rumble. Creek banks caved in and huge trees toppled in a continuous crash of snapping branches. In all the Great Lakes, but especially Lake Michigan and Lake Erie, the waters danced and great waves broke erratically on the shores, though there was no wind. In the western plains there was a fierce grinding sound and a shuddering which jarred the bones and set teeth on edge. Earthen vessels split apart and great herds of bison staggered to their feet and stampeded in abject panic. . . . To the south whole forests fell in incredible tangles. New streams sprang up where none had been before. In the Upper Creek village of Tuckabatchee every dwelling shuddered and shook and then collapsed upon itself and its inhabitants . . . . The Mississippi itself turned and flowed backwards for a time. It swirled and eddied, hissed and gurgled, and at length, when it settled down, the face of the land had changed. New Madrid was destroyed and tens of thousands of acres of land . . . vanished forever; and that which remained was ugly and austere. (pp. 538–540)

Many of Tecumseh's Indian allies accepted this, the first of a series of shocks comprising the great New Madrid earthquake, as the second sign. They joined Tecumseh, along with their British allies, to challenge the Americans. Tecumseh, however, was killed very early in the battle, proving that he had no special power other than the force of his personality. His Indian allies scattered and the Americans went on to defeat the British and secure the Northwest Territories.

Excellent prose about earth pro-

Detail from the painting "The Voyage of Life: Youth" by Thomas Cole, photo courtesy of the National Gallery of Art cesses can also be found in novels and other literature. James Michener, for example, has included very dynamic descriptions in some of his historical novels. In *Hawaii* (1959), he describes the origin of the islands in very vivid prose, providing insight into the volcanic processes that formed and continue to mold the islands.

In *Centennial* (1974), he describes the evolution of the Rocky Mountains over billions of years of time. He devotes a chapter each to the development of the Rocky Mountains, the evolution of the life of the area, and the early presence of humans. Especially interesting is the section on the habitat and life of the dinosaurs that inhabited the region during the Cretaceous period. Their remains are preserved in the famous Morrison formation, which is exposed in a dramatic road cut on the outskirts of Denver.

In his most recent book, *Alaska* (1988), he gives very understandable explanations of how Alaska grew over the past billion years. He accurately describes the processes of plate tectonics that accounted for its formation and the recent ideas of "terranes" that geologists now think accumulated over millions of years to form the Alaskan peninsula. Michener also provides insight into the methods used by geologists to interpret the history of an area, as the following passage shows.

> In one of the far wastes of the South Pacific Ocean a long-vanished island-studded landmass of some magnitude arose, now given the name Wrangellia, and had it stayed put, it might have produced another assembly of islands like the Tahiti group or the Samoan. Instead, for reasons not known, it fragmented, and its halves moved with a part of the Pacific Plate in a northerly direction, with the eastern half ending up along the Snake River in Idaho and the western as a part of the Alaskan peninsula. We can make this statement with certainty because scientists have compared the structure of the two segments in minute detail, and one layer after another of the terrane which landed in Idaho matches perfectly the one which wandered to Alaska. The layers of rock were laid down at the same time, in the same sequence and with the same relative thickness and magnetic orientation. The fit is absolute, and is verified by many matching strata. (p. 5)

Michener's novels, Eckert's historical accounts, and Powell's journals are only a few examples of writing suitable for the science classroom. There are many other writers and poets who, over the years, have provided descriptions that can be substituted for the often dull and stilted writing found in our science texts. It is simply up to teachers to be on the alert for such passages.

The Earth and its processes have been an inspiration to many artists.

Art can also provide illustrations of earth processes. I've been an avid photographer since the 8th grade. Those who share my enthusiasm for the hobby will be familiar with the name Ansel Adams. He was my hero and I have always aspired to photograph landscapes as sensitively and inspirationally as he did.

Adams was born and raised in San Francisco. When he was four, an aftershock of the great earthquake of 1906 knocked him against a brick wall, breaking his nose. His face bore the mark of that earthquake throughout his life. He went on to become an ardent conservationist and one of our most famous photographers. His interpretations of western landscapes is art of the highest merit. But they also illustrate earth processes and can serve as excellent teaching tools. (See photograph on pages 60–61.)

The Earth and its processes have been an inspiration to many artists. One of my favorite art selections is a series of four paintings completed during 1839 and 1840 by the American painter Thomas Cole. Entitled *The Voyage of Life*, they depict the moods of the various stages in the human life cycle. In the detail from "Youth," found on page 62, the verdant shore provides a setting of excitement and energy as the youth looks to a future of promise and productivity. The other paintings depict childhood, maturity, and old age. In each, Cole has used planet Earth and its processes to express his feelings about life and the stages that we all move through.

An inspired teacher will help students experience the planet the way Cole did, to see in Earth processes a reflection of the intimate relationship between humans and their environment, and help them reach an understanding of our dependence upon a rich and fruitful environment and our need to sustain its quality for our own benefit and that of future generations.

Our beautiful Earth

As science teachers, we can appeal to the right brain, as well as the left brain, of our students in our attempts to get them involved in science. They should encounter planet Earth through our courses as a thing of beauty; its processes developing spectacular vistas as they operate over eons of time. They should be able to marvel at the beauty of an ice crystal sparkling in the sun as a glacier melts. They must come to value the Earth, not just for the minerals it gives up to industry, or the oil it provides for our cars, but for the sunsets from its atmosphere and the symmetry in a crystal. As teachers help their students achieve a rational understanding of the Earth and its processes through a study of science, they also can 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. ■

Victor J. Mayer is a professor of science education, geology, mineralogy, and natural resources at the Ohio State University, 1940 N. High St., Columbus, OH 43210.

References

Eckert, A.W. (1967) *The Frontiersman*. Boston: Little, Brown and Company.

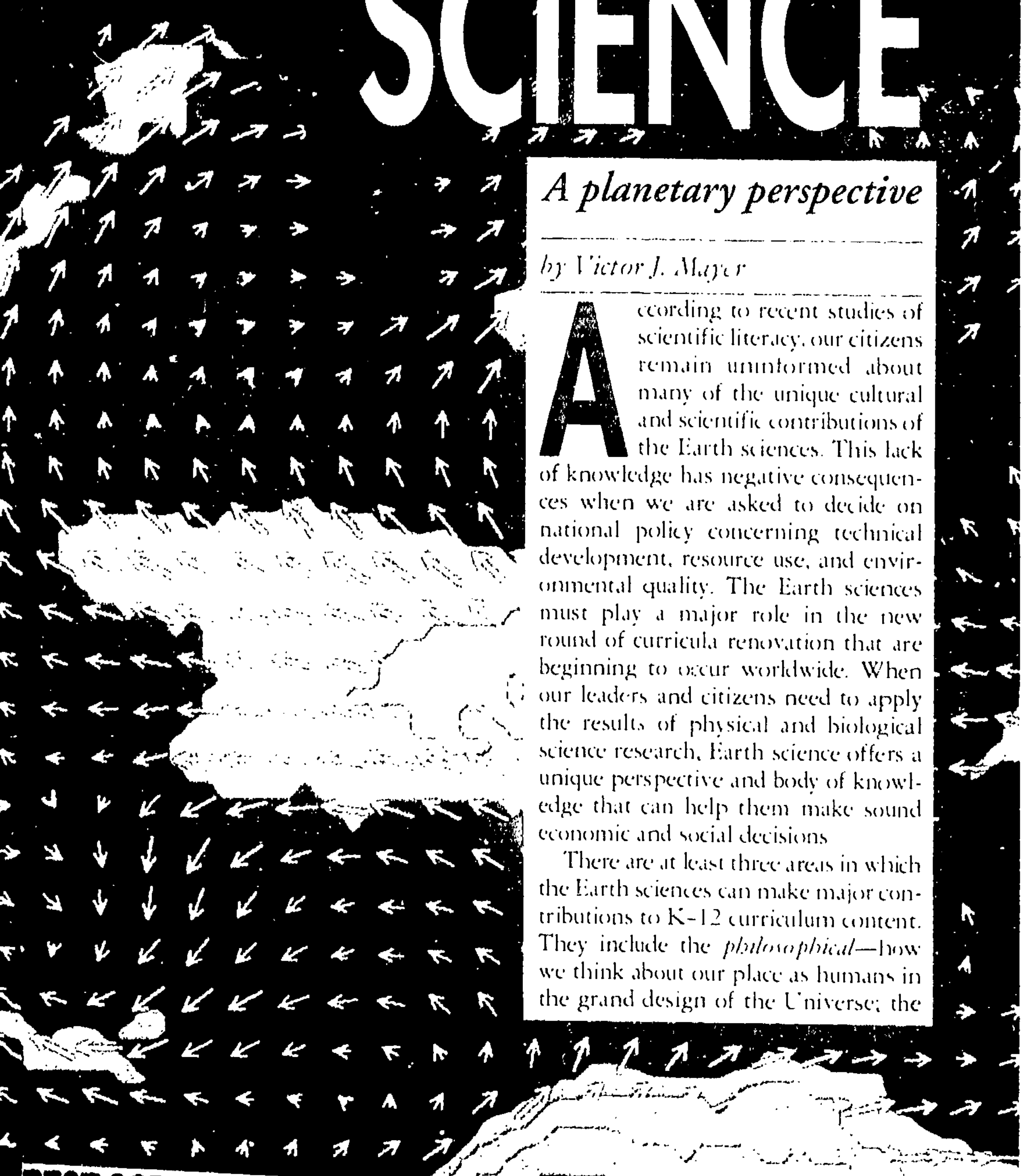
Michener, J.A. (1988) *Alaska*. New York: Random House.

Michener, J.A. (1974) *Centennial*. New York: Random House.

Michener, J.A. (1959) *Hawaii*. New York: Random House.

Powell, J.W. (1957) *The Exploration of the Colorado River*. Chicago: The University of Chicago Press.

EARTH-SYSTEMS SCIENCE

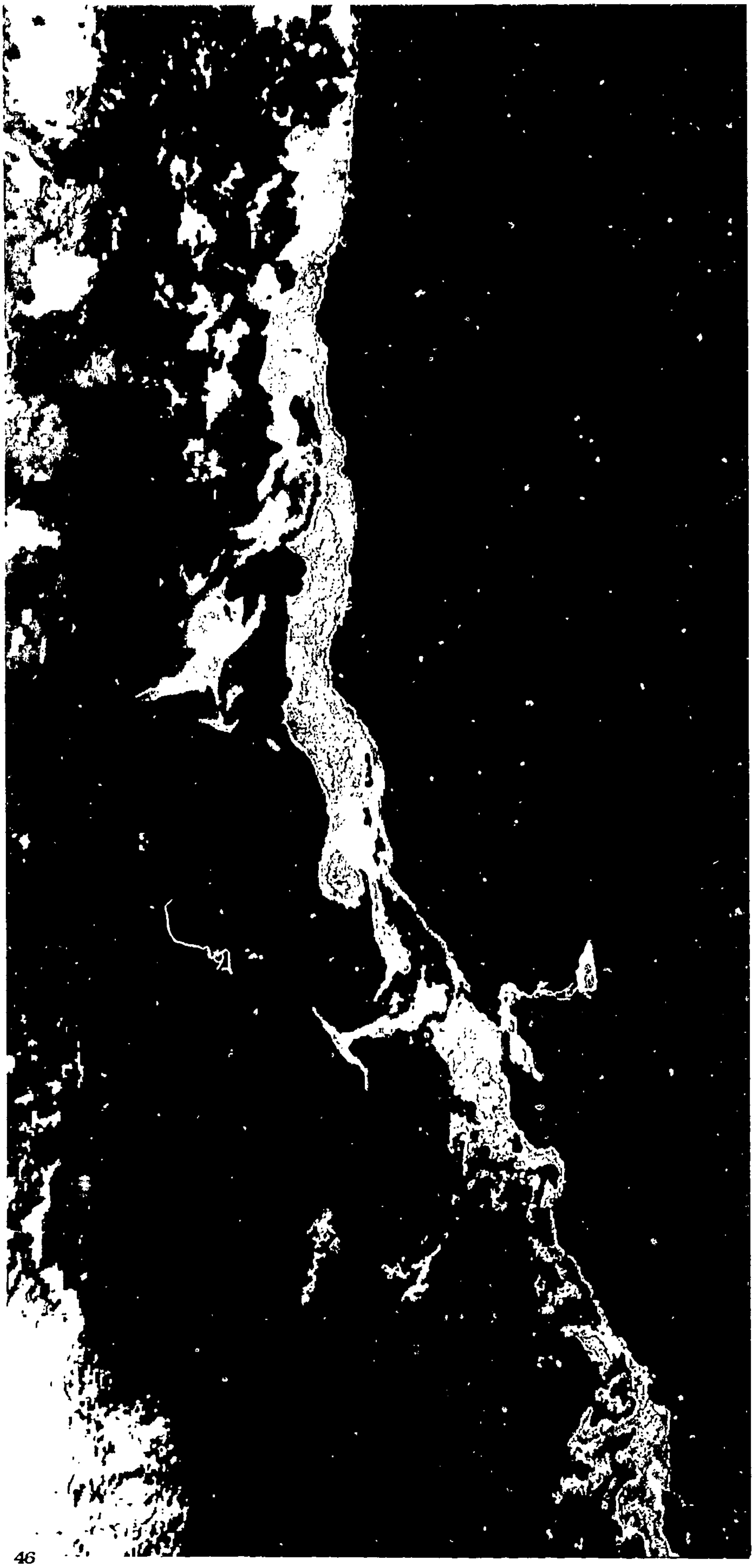


A planetary perspective

by Victor J. Mayer

According to recent studies of scientific literacy, our citizens remain uninformed about many of the unique cultural and scientific contributions of the Earth sciences. This lack of knowledge has negative consequences when we are asked to decide on national policy concerning technical development, resource use, and environmental quality. The Earth sciences must play a major role in the new round of curricula renovation that are beginning to occur worldwide. When our leaders and citizens need to apply the results of physical and biological science research, Earth science offers a unique perspective and body of knowledge that can help them make sound economic and social decisions.

There are at least three areas in which the Earth sciences can make major contributions to K–12 curriculum content. They include the *philosophical*—how we think about our place as humans in the grand design of the Universe; the



ALL SATELLITE IMAGES COURTESY OF NASA

methodological—the intellectual methods that we use in investigating our surroundings; and the *conceptual*—what we know about our world and how it functions.

PHILOSOPHICAL CONTRIBUTIONS

Before James Hutton's *Theory of the Earth* was published in 1795, our planet was thought to be a mere 6000 years old. Hutton's book introduced the concept of "deep time," and 40 years later Charles Lyell expanded on this concept in *Principles of Geology*. Lyell suggested an Earth of great age, upon which "observable processes" developed the features of rocks and landscapes. This concept became the basis for the development of all modern geological concepts. It also set the stage for Darwin (who, soon after Lyell's book was published, took it on his famous voyage) to develop the theory of organic evolution.

These scientific theories have had a great impact on our culture; we can no longer consider the Earth as having been created specifically for man's use. Stephen Gould, in his recent book, *Time's Arrow, Time's Cycle*, quoted Mark Twain's tongue-in-cheek depiction of this attitude:

"Man has been here 32 000 years. That it took a hundred million years to prepare the world for him is proof that that is what it was done for. I suppose it is, I dunno. If the Eiffel Tower were now representing the world's age, the skin of paint on the pinnacle-knob at its summit would represent man's share of that age; and anybody would perceive that that skin was what the tower was built for. I reckon they would, I dunno."

The current attitude that we can squander Earth's resources and somehow be saved from the consequences is not tenable. We now understand that we occupy a planet that has evolved over several billions of years. We, ourselves, are a very recent result of a process that has gone on for an equally long period of time and that has resulted in the extinction of many life forms.

The Earth sciences deal with deep time as a fundamental element in their structure. Therefore, they are the place in curricula where an understanding of this concept must be developed. Teaching for a true understanding, however, is extremely difficult. Gould says:

"An abstract, intellectual understanding of deep time comes easily enough—I know how many zeroes to place after the 10 when I mean billions. Getting it into the gut is quite another matter. Deep time is so alien that we can really only comprehend it as metaphor. And so we do in all our pedagogy. We tout the geological mile (with human history occupying the last few inches) or the cosmic calendar (with *Homo sapiens* appearing but a few moments before 'Auld Lang Syne')."

Teaching about deep time, therefore, requires a great deal of thought and creative effort. One problem is developing an understanding for immense numbers such as a million or billion. To put things in perspective, one eighth grade Earth science teacher has the students in each of his classes count dots printed on pieces of paper. When one sheet has been counted it is taped to the wall. By the end of the day, the walls are covered and the cooperative count has reached only one million. Another Earth science teacher has his students use their bodies to construct the geologic time scale. Using a scale of one meter to 10 million years, students place themselves at different events on the time scale. In this way they become intimately involved with both the events and the relative time in which they

occurred. The resulting time scale stretches the entire length of the school building (450 m).

Deep time is just one concept that has helped us understand our place in the Universe. Equally important was Copernicus' restructuring of the solar system into a heliocentric model and the subsequent understanding of the place of the solar system itself within the Galaxy and the Universe. It has become more and more difficult to think of the world as having been created solely for us—to be used as we see fit; it was this attitude that is responsible for the environmental problems we are now facing. The concept of organic evolution has further eclipsed the egocentric philosophy. We are only one branch of a long series of developments that has survived because the previous branches lived in harmony with their environment.

THE METHODOLOGICAL CONTRIBUTIONS

The Earth sciences provide an excellent opportunity for students to learn the problem solving approaches of the scientist. Students can experience weather systems, observe weathering taking place, and interpret landscapes in the vicinity of their homes. Such experiences can entice them into searching out a deeper understanding of the nature of scientific investigation.

Steven Gould, in his address to the 1987 NSTA convention, decried the low status given the methods used by Earth scientists, such as the historical method. The experimental method is held up as the hallmark of science in elementary and secondary science teaching; however, it is the historical and descriptive methods that have given us the truly powerful ideas about ourselves and our place in the Universe. After all, Copernicus did not perform experiments to reorder the solar system with the Sun at its center, nor did Darwin perform experiments to create his theory of evolution.

In reality, there is no one method of science. What marks science as a discipline is the gathering of real-world data and the objective analysis of that data to gain meaning for how the world operates. Conducting experiments is simply one way of obtaining data. They are usually conducted to verify ideas derived from data obtained by observations and descriptions of Earth's processes. But our students believe that the only science is experimentation. They are led to believe that experiments are the only way to experience "hands-on" science. But there are many ways the Earth science teacher can exemplify the historical and descriptive approaches in a "hands-on" mode: for example, by charting changes in a stream over time, or gathering and analyzing weather data.

Deep time is just one concept that has helped us understand our place in the Universe.

The discovery of deep time, the development of the theory of evolution, our understanding of our Universe, and the knowledge we now have of our planet's evolution and its environs are basic concepts underlying western thought and philosophy. They are not the result of experimentation, but of the application of the historical methods of the Earth scientist.

The Crustal Evolution Education Project of the National Association of Geology Teachers developed over 32 activities on plate tectonics (available from Wards Science Establishment, Inc.). Many exemplify the historical and descriptive approaches of the Earth scientist, and we as science teachers can use them to acquaint our students with the thought processes behind such methods. They include, for example, activities on Iceland (where students plot data on rock ages), paleomagnetism, and earthquakes. Working as teams, students analyze the data, and, based on their interpretations, determine the location of the mid-Atlantic Ridge as it crosses Iceland.

Other activities use data from deep sea cores to verify the spread of the Mid-Atlantic ocean basin, or paleomagnetic data to determine the relative positions of India as it moved up to impact the Asian continent.

THE CONCEPTUAL CONTRIBUTIONS

We are now able to look at the Earth in a dramatically different way. Instead of being forced to examine small areas of terrain or local atmospheric changes, scientists can now view the planet holistically. This has been made possible because of many advances in technology. Sophisticated satellites can observe biological, chemical, geological, and physical changes over enormous areas. Supercomputers now permit the reduction and analysis of huge amounts of data. Communication networks link scientists from many different places on the Earth to work simultaneously on the same projects.

Partly as a result of applying these new tools to the study of our planet,

FIGURE 2. The seven understandings from the Framework for Earth Systems Education (courtesy of The Ohio State University).

- Earth is unique, a planet of rare beauty and great value.
- Human activities, collective and individual, conscious or inadvertent, are seriously impacting planet Earth.
- The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
- The Earth system is comprised of the interacting subsystems of water, land, ice, air, and life.
- Planet Earth is more than four billion years old and its subsystems are continually evolving.
- Earth is a small subsystem of a solar system within the vast and ancient Universe.
- There are many people with careers that involve study of Earth's origin, processes, and evolution.

NOTE

The complete Earth Systems Framework (abstracted in Figure 2) and information about the Program for Leadership in Earth Systems Education is available from the author.

REFERENCES

Gould, S.J. 1987. *Time's Arrow, Time's Cycle*. Cambridge: Harvard University Press.

Hutton, J. 1795. *Theory of the Earth with Proofs and Illustrations*. Edinburgh: William Creech.

Lyell, C. 1830–1833. *Principles of Geology, Being an Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation*. London: John Murray.

Mayer, V.J., and R.E. Armstrong. 1990. What every 17-year-old should know about planet Earth: A report of a conference of educators and geoscientists. *Science Education* 74(2):155–165.

Earth scientists now speak of the Earth as a system. Rather than having to restrict their study to processes that can be observed in one place at one time, or a few places at several times, they can now look at processes occurring on a global scale and in a time frame stretching back tens of millions of years. Thus we are beginning to receive the first glimmer of understanding of how the Earth system works and how each of its subsystems, such as lithosphere, atmosphere, and hydrosphere interact with each other to produce global changes. It has also been evident that humans and their activities have been a very important agent in changes that have occurred in the past, and will occur in the future. This is now a different planet that we are living on; a complete revolution in our knowledge of our home has occurred. Unfortunately, however, little of this new knowledge has found its way into the curriculum.

Global changes can be thought of as occurring on two different timescales. One is on the order of thousands to millions of years, and includes processes such as plate tectonics, the gradual evolution of mountains, ocean basins, and other large features of the Earth's crust. The other changes occur on the order of decades to centuries, and include processes in subsystems such as the biosphere and atmosphere. It is the latter that is most influenced by our activity—global warming, for example—and therefore of most immediate concern.

To teach these Earth concepts, instructors should use the results of the new technology epitomized by current satellite imagery. In 1977, NASA published *Mission to Earth: Landsat Views the World*, which includes a wealth of high altitude imagery. In 1978, NASA followed with an educators guide that contains ideas on how to use the images. More recent imagery available from NASA allows students to study upwellings and the consequent bloom of phytoplankton, variations in the level of the sea, and the direction of wind at the sea surface on the scale of continents and ocean basins (Figure 1).

A national project is now underway to implement many of the understandings discussed above into the K–12 science curriculum. The Program for Leadership in Earth Systems Education (PLESE), recently funded by the National Science Foundation, is preparing K–12 teacher teams to implement Earth Systems syllabi in their own classrooms and to conduct workshops in their states and locales.

The planning committee of the project, using the results of a 1988 conference of geoscientists and educators held in Washington, D.C., and an analysis of Project 2061 Earth science concepts, developed a framework of seven understandings (Figure 2). PLESE teams organized at summer workshops at the Ohio State University or the University of Northern Colorado used the framework as a guide in developing Earth systems syllabi and in selecting materials to implement the syllabi. Through programs such as this, curricula is developed that will provide our students with a much richer understanding of the nature of science, and more importantly, the nature of the planet on which they live. With such understandings, we as a society will be better prepared to meet a future in which all is changing; our world's economics, politics, and environment.

Victor J. Mayer is a professor of Science Education, Geology and Mineralogy, and Natural Resources at Ohio State University, 1945 N. High St., Columbus, OH 43210, and is the director of the Program for Leadership in Earth Systems Education.

What Every 17-Year Old Should Know About Planet Earth: The Report of a Conference of Educators and Geoscientists*

VICTOR J. MAYER
Department of Educational Studies, The Ohio State University, Columbus, OH 43210

RONALD E. ARMSTRONG
South Glens Falls (NY) Public Schools

Introduction

There is great public concern regarding the quality of science curricula in the nation's schools. This concern has resulted in a number of efforts to redefine curriculum and especially to identify the curricular bases for scientific literacy. Perhaps the most prominent of these efforts is that of the American Association for the Advancement of Science, Project 2061 (AAAS, 1989). Such efforts in the past have, in the opinion of some science educators, neglected Planet Earth despite the fact that one could consider the entire domain of science as being an effort to understand our planet and how its processes work. Curriculum efforts, like the science disciplines that sponsor them, have often taken a reductionist approach focusing on the specific contributions of certain scientific disciplines in understanding concepts and processes within their defined domain, failing to relate them to the earth system in which they operate and interact with other processes and concepts. But, whereas scientists have seen the limitations of the traditional science disciplines and have spawned a variety of interdisciplinary efforts to understand basic processes, the science curriculum is trapped in the century old curricular straight-jacket of biology, chemistry and physics. This seems to have insured the neglect of the planet earth systems that are our home and govern our well-being.

To provide a basis for an adequate representation of Planet Earth in the current curriculum efforts, a conference of educators and geoscientists was held in Washington, D.C. in April, 1988. The four and one-half day conference identified those

* This is a portion of a report published and copyrighted by the Ohio State University Research Foundation. Permission has been granted for its reprinting here.

Science Education 74(2): 155–165 (1990)

CCC 0036-8326/90/020155-11$04.00

goals and concepts about Planet Earth that every 17-year-old should know when completing pre-college education. The sponsors of the conference were the American Geological Institute and the National Science Teachers Association. The results of the conference have wide-spread implications for the content of curriculum materials and instruction in K-12 science and geography courses. This article is an adaptation of a report of the conference published by The Ohio State University (Mayer, 1988).

Background

Participants in a meeting of educators and geoscientists held in September, 1985, concluded that the top priority for improving programs in earth science education was the development of a K-12 earth science syllabus. Those attending the meeting, held at the headquarters of the American Geological Institute (AGI) in Alexandria, VA, and supported with a grant from the National Science Foundation (NSF), also concluded that such a document if it bore the endorsement of both the scientific and science education communities would have a strong impact on the content of textbooks, state and local curriculum guides, and state and national tests. Participants felt that it would provide guidance for educators and scientists in conducting cooperative efforts to improve the teaching about Planet Earth in the nation's schools.

In Autumn, 1987, several science educators and science agency representatives in Washington, D.C., after lengthy discussions, concluded that the first step in developing such a syllabus would be to convene a conference of eminent scientists to identify the components of our current knowledge of Planet Earth that have relevance for the K-12 curriculum. Conversations with representatives of the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS), and the Directorate of Geosciences for NSF led to agreements to identify and support three or four scientists each to participate in such a conference. The scientists were selected within each agency using four criteria. Any scientist selected should:

1) be recognized by peers as a leader in the discipline.
2) have a broad knowledge of earth systems and be able to see beyond his/her specialty to the broad conceptual fabric of earth systems.
3) have an interest in science education and have a commitment to help improve the science curriculum.
4) be an effective communicator.

Nineteen scientists meeting these criteria participated in the conference.

The conference organizers (see Appendix) felt that scientists by themselves would have a difficult time completing the conference task since few would have any direct experience with schools and science curricula. Thus it was decided to invite about twenty teachers, supervisors and science educators as conference participants. They would bring knowledge of the nature of children and of the teaching task to the conference, providing a point of reality that would ensure that the understandings identified by the conference would indeed be those that every 17-year-old could know and understand. The educators were selected on the basis of the quality of their science backgrounds and their records for leadership in their own school systems and nationally. In addition, care was taken to ensure representation geographically, by grade level taught, and by role within the educational establishment. As a result there were elementary, middle school and high school teachers, state level science consultants and university science educators represented among the participants. The educators found their own sources of support for the conference primarily from their school systems and universities. AGI received a grant from the Science and Engineering Education (SEE) Directorate of NSF to cover the administrative and logistic costs.

The conference, therefore, had a national perspective resulting from participation of scientists from three science agencies each with a national mission (NASA, USGS, and NOAA); scientists from universities in Oregon, California, South Carolina, Massachusetts, and Oklahoma; science educators from universities in Minnesota, Missouri, and Ohio; and supervisors and teachers from Washington, Idaho, California, Texas, Michigan, Ohio, North Carolina, Virginia, and New York. Its conclusions, therefore, can indeed represent a national agenda for reforming what is taught about Planet Earth in our nation's schools.

The Conference Charge

It had been over twenty years since the science community had been closely involved with educators in identifying the concepts in the earth science disciplines that should be taught K-12. Because of the technical advances provided during that time in data gathering and processing and the intensive investigations of the earth system, our knowledge of Planet Earth had changed dramatically. The charge to the conference was to identify those understandings about Planet Earth that every citizen needs to know in order to live a responsible and productive life in our democracy.

In attempting to fulfill the charge, the keynote speaker, Dr. F. James Rutherford, Director of Project 2061 of the American Association for the Advancement of Science, cautioned the participants to avoid the usual pitfalls of such efforts. He advised the group to discuss curriculum, not courses; not to buy in to the status quo of the existing curriculum structure but to consider the place of earth concepts in the total purview of science. Identify the concepts or processes that are important for the well being of citizens, not those that might contribute at some later undefined time to the understanding of some equally hazily defined goals. Rutherford is concerned, as are many science educators, that the current science curriculum is "bloated and overstuffed." Students are required to memorize a vast array of trivia, most of which is forgotten soon after the test. He warned the participants not to add to that problem. In deciding on what new concepts to include, participants should also decide what old concepts should be eliminated from the curriculum. This trade-off always needs to be in mind. In addition, the elements identified for inclusion must contribute to the general aims of education.

Rutherford emphasized the need for curriculum to reflect the current requirements of our social and economic systems and the basic understanding of the nature of scientific investigation. The various science disciplines are now intimately intertwined. Mathematics is the essential tool of modern science. More and more science is applied in industry and defense. Citizens must develop a fuller understanding of how technology is used in our society. They must have a clear understanding of evidence as the real authority in science, of the power of theories in the investigation of nature, of science as a conservative enterprise requiring replication and openness. There needs to be a focus on the unifying themes, such as systems, models, and evolution.

In choosing facts and concepts he warned participants not to fall into the trap of "watering down" ideas from the sophisticated ideas that "all scientists must understand." Instead, identify what is fundamental, then build on that structure. Rutherford suggested several criteria that should be applied in making judgements regarding possible curricular elements:

1. What is the scientific significance? Will the concept or fact still be around in the next generation?
2. What is the human significance of the idea? How does it affect or influence citizens?
3. What is the philosophical power of the idea? How does it contribute to our understanding of the world?
4. What is its current importance to our social and economic well-being?
5. How does it contribute to personal enrichment? Does it make the world of the pre-18-year-old more interesting?

Rutherford concluded with several general suggestions. He invited the earth science education community to join in the total school reform movement. This is one of those times in history when it is possible to reconstruct the educational system. He encouraged all to participate in designing the system of tomorrow. Think K-12, infiltrating the entire curriculum with Planet Earth concepts. Emphasize the concrete, how things work, the dynamics of the earth system. Feature the connections to the other sciences. Make those sciences more interesting to students by showing how they can be applied to Planet Earth problems or concepts. Give priority to ideas and methods rather than words. Beware of authoritarianism, be open to the inclusion of new concepts, ready to discard the old.

Organization

As soon as each scientist was identified he/she was sent a letter requesting the development of a short, three-page paper outlining his/her preliminary ideas regarding what every high school graduate should know about her/his field of inquiry. They were then compiled and sent to each of the participants about one week prior to the beginning of the conference. These papers provided the focus for the first round of discussions. Scientists were assigned to one of four groups based upon their specialty. An equal number of educators were assigned to the groups such that each scientist was teamed with an educator. Each of the resulting groups of about eight individuals each were led by a facilitator. Each group was to reach consensus on the goals and concepts regarding Planet Earth to be included in the education of every citizen. Each day started with a presentation to the entire group. Rutherford's keynote address was followed on the next day by a talk by Dr. Audrey Champagne from the Office of Science and Technology Education of the AAAS. It focussed on learning problems afforded by misconceptions or naive theories. On the third day, Dr. Dallas Peck, Director of the United States Geological Survey, presented a talk outlining his perception of the place of the earth sciences in the general education of our citizens. The general presentation was followed each day by two small group sessions, one immediately after the talk and the other following the lunch break. Participants were brought together again at the end of the afternoon for two one-half hour presentations by participants on topics of general interest.

At the end of each day the small groups recorded the results of their discussions. These were typed reproduced and made available for their deliberations the following day. On the third day of the conference, the groups were reassembled such that each of the new groups included an educator-scientist team from each of the previous groups. The charge to three of the groups was to integrate the conclusions from all four groups into a single set of recommendations. This resulted in three versions. On the afternoon of the fourth day of the conference these three versions were integrated by the total group through the use of group dynamics processes, such that consensus was reached on each aspect of the framework that resulted. The fourth group was asked to develop a set of guidelines for the development of a senior high school earth systems course.

On the morning of the fifth day, most of the educators assembled to put the finishing touches on the conclusions of the conference. At this session wordings of the goals and concepts were agreed upon, and a preamble for the conclusions was developed.

Conference Results

Following are the results of the conference. Minor editing has been done to improve reading style, but the substance remains identical to that agreed to by the participants.

Preamble

As the 21st Century dawns, we find ourselves in the midst of a revolution in our knowledge concerning Planet Earth. It is imperative that every 17-year-old develop an understanding of Earth concepts as well as appreciate the beauty of the Planet Earth.

The Earth seen from space is both metaphor and reality of a deepening consciousness of the integrated view of our planet necessary for its successful stewardship. Catalyzed by an accelerating technology, a holistic view incorporating dynamic images and ideas provides incredible opportunities to ignite the imagination of American students.

Our report outlines the goals and concepts that are a prerequisite for an evolving 21st century view of Planet Earth. To imbue this framework with the spirit of revolution intended, educators should recognize the importance of the following issues:

1. Emphasize K-6
2. Demand a hands-on, investigative approach
3. Encourage and include minorities and women throughout the process
4. Integrate the various science disciplines and emphasize geographic ideas
5. Incorporate more mathematics, computers and emerging technologies
6. Develop issue oriented case studies
7. Involve parents and the community
8. Capture the excitement and fun of learning about Planet Earth

Goals

SCIENTIFIC THOUGHT. Each citizen will be able to understand the nature of scientific inquiry using the historical, descriptive and experimental processes of the earth sciences.

KNOWLEDGE. Each citizen will be able to describe and explain earth processes and features and anticipate changes in them.

STEWARDSHIP. Each citizen will be able to respond in an informed way to environmental and resource issues.

APPRECIATION Each citizen will be able to develop an aesthetic appreciation of the earth.

Concepts

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

   The sun is the primary source of Earth's energy.

   The sun is one of the billions of stars in the universe.

   The moon and Earth affect each other.

   All bodies in space (including Earth) are influenced by processes acting throughout the solar system and the universe.

   The nature of each planet is determined by its position in the solar system and by its size.

The position and motion of Earth with respect to the sun influence tides, seasons, climates, etc.

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

   Water exists as a vapor, liquid and solid and changes form as a result of changes in energy.

   Oceans are in constant motion and are a resource that covers over 70% of the planet.

   The cryosphere (frozen water) is an Earth subsystem that has varying seasonal and global distribution.

   Atmospheric circulation is driven by solar heating and modified by interactions with other subsystems.

   The solid earth (lithosphere, asthenosphere) interacts with the hydrosphere, atmosphere, cryosphere and biosphere.

   The biosphere interacts with other subsystems.

   The sun is a major source of energy that influences the earth system.

   Geothermal energy influences the dynamics of earth systems.

   Each component of the earth system has characteristic properties, structure and composition.

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

   Water cycles through the subsystems.

   The outer layer of the solid earth is composed of plates which are and have been in motion.

   All new rocks are derived from old rocks by recycling.

   Major examples of the interaction between components of the earth system are the hydrologic cycle, rock cycle, carbon cycle, glacial cycle, trophic cycle.

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

   Physical processes in the universe range over time scales of seconds to billions of years and over very great distances.

Earth is more than 4 billion years old and is continually evolving.

The atmosphere is a thin, protective blanket composed of various gases and other substances that evolve over geologic time.

Fossils are the evidence that the biosphere has evolved interactively with the earth over geologic time.

Evolution results in a sequence of unique historical changes of Earth's subsystems. For example: changes in atmospheric composition, changes in life forms, changes in structure of the solid earth, changes in the composition of the hydrosphere.

Time scales for Earth changes are variable. For example:

Long-term evolution of the solid earth and atmosphere (4.5 × 10 years)
evolution of life (4 × 10 years)
break-up of Pangaea 5(1.8 × 10) years
ice ages
extinction of plants and animals
drought
seasons
daily weather
nuclear reactions

Short-term chemical reactions

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 minerals and water.

7. Human activities, both conscious and inadvertent, impact Earth subsystems

Human use activities influence the:
hydrosphere and vice versa.
cryosphere and vice versa.
atmosphere and vice versa.
lithosphere and vice versa (mining, hazards, etc.)
biosphere and vice versa

Human activities exert inordinate impact on the global environment. Human activities alter Earth's components such as burning fossil fuels, improper land use, war and war preparations, releasing hazardous chemicals and radioactive materials, releasing and disposing hazardous materials, extinction of species.

8. A better understanding of the subsystems stimulates greater aesthetic appreciation.

   Humans appreciate and manage the Earth by preservation, appropriate utilization and restoration. For example: natural parks, reclamation, conservation, recreation, legislation, land managment and planning, international to local cooperation.

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

   Technology has improved our ability to understand the earth. For example: optical and electronic microscopes, optical and radiotelescopes, infrared sensing, doppler radar, submersibles, satellites, computers.

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.

    Observations of the atmosphere are used to forecast weather.

    Maps are scale models of the Earth

    Knowledge of other planets helps us understand the Earth

Analysis of Conference Results

On the last day, during the final editing of the conference recommendations, someone asked whether the results were any different than those from similar conferences held twenty years ago. Several of the educators were familiar with the Earth Science Curriculum Project, the last major effort in earth science curriculum renewal. They felt that the differences were dramatic. Content relating to the third goal, stewardship, was hardly considered for inclusion in the ESCP materials. Goal four, aesthetic appreciation of the earth, would not have been thought of as appropriate when considering science curriculum. It is clear that the scientific community has changed in its attitudes and values in the ensuing years.

The results of this conference are consistent with current movements in science curriculum revision that are exemplified by Project 2061. The participants were not only able to think beyond the current goals of science and science teaching, but to go beyond them in a creative and enthusiastic manner. The recommendations reflect the challenge that Rutherford made in his opening talk to not be bound by the past and to think creatively as to what curriculum can be. Thus they in turn challenge the science education community to develop a curriculum that is dramatically different, one that adequately incorporates a modern knowledge of Planet Earth, the manner in which we investigate our home, the implications of technology for our future habitat and an appreciation for the beauty implicit in our earth systems. Science educators are challenged to incorporate an understanding of students and how they come to investigate the earth into planning future curriculum and teaching.

The Next Steps

This conference represents the first national effort in over twenty years to involve geoscientists in a significant way in the identification of appropriate curriculum content regarding Planet Earth. As such it is a first step. The framework developed by the conference must now be translated for the use of classroom teachers, textbook publishers, test developers and curriculum specialists. This will require the cooperation of many different organizations and individuals in science, science education, and educational policy development and implementation.

References

American Association for the Advancement of Science (1989). *Science For All Americans* Washington, DC: AAAS.

Mayer, Victor J. (1988). *Earth Systems Education A New Perspective on Planet Earth and the Science Curriculum.* Columbus, OH: The Ohio State University Research Foundation

Accepted for publication 26 September 1989

Appendix

Conference Coordinators

Dr. Ronald E. Armstrong
South Glens Falls School District
South Glens Falls, NY 12801

Dr. Victor J. Mayer
The Ohio State University
1945 North High Street
Columbus, OH 43210

Group Facilitators

Dr. Lloyd H. Barrow, Department of Science Education
University of Missouri-Columbia

Ms. Jane N. Crowder, Earth Science Teacher
Isaquah (WA) Public Schools

Dr. Fred N. Finley, Curriculum and Instruction Department
University of Minnesota

Dr. Arie Korporaal, Consultant, Science Education
Los Angeles County Office of Education

Participants

A complete list of participants can be obtained from the authors.

NORTH AMERICAN ASSOCIATION FOR ENVIRONMENTAL EDUCATION

A Place for EE in the Restructured Science Curriculum

Rosanne W. Fortner, The Ohio State University

Reprinted from Baldwin, J. H. (ed.), 1991. *Confronting environmental challenges in a changing world.* Troy, OH: North American Association for Environmental Education.

"Neither environmental education (EE) nor any of its predecessors or variants has traditionally had a curricular home of its own," wrote Disinger in his 1989 report of a national survey of EE in U.S. schools. Perhaps this is because environmental educators have insisted that environment belongs to the total curriculum, with a place in every subject and grade (Simmons, 1989), and therefore appropriate niches have been sought throughout the available curriculum. The benefits of such an infusion approach are numerous in light of the swinging pendulum of educational interest: infused EE is not seen as an additional burden on the overstuffed curriculum, nor is it as vulnerable when other priorities or budget constraints decree that something has to go. Philosophically, infusion confirms the interdisciplinarity of EE and its importance in relation to all aspects of human existence.

> *"The existing science curriculum is now under scrutiny for purposes of restructure, and questions should arise about where EE will fit in any new scheme that develops."*

Indeed, Disinger's (1989) survey confirmed that infusion is the most common form in which EE is practiced in U.S. schools. As for the impact of this approach over time, few studies have been conducted. Taylor and Fortner (1989), however, found in a statewide survey of Ohio secondary schools that from 1982 to 1986 twice as many schools had dropped EE courses as had added them. The greatest number of infused EE topics in that study were in earth science courses.

The existing science curriculum is now under scrutiny for purposes of restructure, and questions should arise about where EE will fit in any new scheme that develops. The most extensive efforts underway are Project 2061 (AAAS, 1989) and NSTA's Scope, Sequence and Coordination (SS&C, 1991). In 2061, Phase I, disciplinary groups identified what every 17-year-old should know about science upon leaving high school. The environment enters consideration only piecemeal as discrete disciplinary science content, but some of the implementation efforts in Phase II are exploring topics such as water as an integrating theme. In SS&C, environmental education has a potential place because of planned emphases on cross-disciplinary teaching. Hence, EE could find a home in SS&C's treatment of ENERGY, among other topics. How SS&C would implement curriculum restructure is still uncertain, and there has been a general lack of consideration of Earth in initial planning.

Instead of "fitting in" to the plans of others with multiple agendas for science education, perhaps "the time is ripe for environmental educators to move aggressively into the dialogues and help the public and the educational establishment see how the ideas environmental educators have been wrestling with can be incorporated *into the very core of a revamped educational system*" (Roth, 1988; emphasis added).

Another, lesser known but equally ambitious, curriculum restructuring effort invites such an opportunity. Earth Systems Education (ESE) is an effort that has arisen out of the interaction of geoscientists, science educators and teachers who feel that the time has come for Earth to resume its appropriate position as the focus of science learning. After all, it was attempts to learn about the Earth that were the origin of all of the sciences as we know them. We have come too far from those origins, and now face the problems of learning science facts dissociated from the realities of human interactions with Earth.

> *"...the time has come for Earth to resume its appropriate position as the focus of science learning."*

Beginning with a prior synthesis of concepts from a conference of geoscientists and educators (Mayer and Armstrong, 1990), and adding the Earth systems concepts of Project 2061, a "Framework for Earth Systems Education" (Figure 1) has been developed (Mayer, 1991). The Framework identifies the reason for environmental education as the first Understanding, essentially, "we've got a great place here."

This Understanding stresses the creativity of the human spirit and sees science as a creative human endeavor. By focusing on students' feelings toward the Earth system, the way in which they experience and interpret those feelings, they are drawn into a systematic study of their planet. Understanding #2 is the mission of EE, namely Earth stewardship. The subject matter of EE is embodied in Understandings #4 and #5, and part of its approach is in #3.

These seven critical understandings are the basis of the Program for Leadership in Earth Systems Education (PLESE), developed at The Ohio State University and supported by the National Science Foundation's Teacher Enhancement funds. From 1990-93, teacher leaders, administrators, and college liaisons are participating in summer programs at Ohio State and the University of Northern Colorado, and then bringing the ESE notion and implementation ideas back to their local areas for additional outreach into the K-12 curriculum. The Understandings are used to structure the enhancement and follow-up workshops and to select materials for implementing Earth Systems Education in various parts of the country.

For environmental educators, ESE offers a content home, and many feel a content base is critical to EE program longevity (Warfield, 1981). It offers a K-12 design, interdisciplinary approach, and combination of humanities, science, and technology as advocated specifically in *A Nation at Risk*. ESE is seen as being taught best through collaborative learning techniques, another positive aspect for EE, since such approaches simulate the kinds of interactions common among decisionmakers in both science and public policy. The scientific methods used in ESE include not only the traditional experimental approach but the historical method. At best experiments are only simulations of how scientists work, and most environmental problems do not lend themselves well to experimentation. More appropriately, ESE emphasizes the analysis of records of continuously collected data and what they reveal about patterns of Earth processes. With the advent of computer and CD-ROM technology, students can now use the same data scientists manipulate to study the phenomena of the Earth subsystems: biosphere, hydrosphere, lithosphere, and atmosphere. Classroom technologies are being explored for use in ESE applications.

"For environmental educators, ESE offers a content home, and many feel a content base is critical to EE program longevity"

Dramatic changes occurring in science and in science education, and impacts of human uses of technology and the environment, require that environmental education be a major component of the restructured curriculum. We must develop a citizenry that understands the functions and limitations of science and technology as they impact the Earth and life upon it. Earth Systems Education is an opportunity for reaching these goals. According to Mayer (1991), "As a first step it provides for infusing planet Earth concepts into all levels of the K-12 science curriculum. For the long run it provides an organizing theme for a K-12 integrated science curriculum that could effectively serve the objectives of scientific literacy

Figure 1. Framework for Earth Systems Education

Understanding #1.	Earth is unique, a planet of rare beauty and great value.
Understanding #2.	Human activities, collective and individual, conscious and inadvertent, are seriously impacting planet Earth.
Understanding #3.	The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
Understanding #4.	The Earth system is composed of the interacting subsystems of water, land, ice, air, and life.
Understanding #5.	Planet Earth is more than 4 billion years old and its subsystems are continually evolving.
Understanding #6.	Earth is a small subsystem of a solar system within the vast and ancient universe.
Understanding #7.	There are many people with careers that involve study of Earth's origin, processes, and evolution.

and at the same time provide a basis for the recruitment of talent into science and technology careers, helping to ensure appropriate economic development consistent with maintaining a quality environment" (p. 20).

References cited

American Association for the Advancement of Science. *Project 2061: Science for all Americans*. Washington, DC: Author.

Disinger, John F. 1989. The current status of environmental education in U.S. school curricula. *Contemporary Education* 60(3):126-136.

Mayer, Victor J. 1991. *Earth systems education: Origins and opportunities*. Columbus: OSU Research Foundation.

Mayer, Victor J. and Ronald E. Armstrong. 1990. What every 17-year-old should know about Planet Earth: A report of a conference of educators and geoscientists. *Science Education* 74(2):155-165.

Roth, Charles E. 1988. The endangered phoenix: Lessons from the firepit. *Journal of Environmental Education* 19(3):3-9.

Scope, Sequence, and Coordination of Secondary School Science. Volume I. The Content Core. A Guide for Curriculum Designers. 1992. Washington, DC: National Science Teachers Association.

Simmons, Deborah. 1989. More infusion confusion: A look at EE curriculum materials. *Journal of Environmental Education* 20(4):15-18.

Taylor, Timothy and Rosanne Fortner. 1989. Environmental education efforts in Ohio high schools in the 1980s. *Ohio Journal of Science* 89(4):98-101.

Warfield, John N. 1981. *Designs for the future of Environmental Education*. Washington, DC: U.S. Department of Education.

Down to Earth Biology

A Planetary Perspective for the Biology Curriculum

Rosanne W. Fortner

INCREASED attention to the biosphere's relationship to the other Earth subsystems—hydrosphere, lithosphere, atmosphere—could help enhance student understanding in biology. Recent international comparison studies do not speak well for levels of biology achievement in the United States. Our 13 year olds ranked ninth out of 12 countries/provinces in the life sciences. Even our advanced students in second-year biology place at the bottom of a list of 14 countries (Jacobson & Doran 1988). The literature of science education is a further reminder that all is not well within the biology curriculum. Studies of naive conceptions demonstrate a lack of basic understanding of concepts such as nutrient cycling, natural selection (Greene 1990) and the water cycle (Bar 1989). A number of these difficulties rest at the interface of biology and Earth sciences.

Bringing biology "down to Earth" might also be the key to making sound decisions on matters of national policy and international assistance. Deforestation, for example, is an atmospheric issue, not just a biological one; ozone depletion creates human health problems; abuses of the ocean are manifested in human habitats and marine mammal welfare; and an understanding of organic evolution rests on a fundamental awareness of "deep time," describing the great age of Earth as revealed through its geologic structure.

The Earth system can become the conceptual base of the science curriculum and play a major role in the restructuring efforts now underway through the American Association for the Advancement of Science's Project 2061 and the National Science Teachers Association's Scope, Sequence and Coordination. When our leaders need to apply the results of biological research in making decisions, the earth sciences can offer a unique perspective and body of knowledge.

According to Vic Mayer, leading advocate of a modern movement in earth systems education (Mayer 1991a), contributions of earth science to the K-12 curriculum take at least three forms:

- Philosophical—how we think about the position and role of humans in the universe
- Methodological—how we investigate our surroundings
- Conceptual—what we know about our world and how it functions.

The purpose of this article is to explore examples of how the biology curriculum could build upon these contributions to achieve greater relevance for students and greater value as a basis for decision making.

Philosophical Contributions

One of the major obstacles to acceptance of evolution as a valid scientific concept is a lack of understanding of the age of the Earth. Before James Hutton wrote *Theory of the Earth* in 1795, the planet was assumed to be only about 6000 years old. It was Hutton who introduced the concept of deep time. Earth processes like those in action today have been going on throughout the history of the planet, and this concept of "the present is the key to the past" (Lyell 1830–1833) forms the basis for all our studies of the Earth. Charles Darwin accepted this idea and applied it in developing his theory of organic evolution.

In accepting the Earth as being of great age one can reject the idea that the world was created specifically for human use. We now understand the planet evolved over billions of years, and the human species is a very recent result of a biological evolution. Because some species have become extinct along the way, there is reason enough to believe that we may not be the ultimate and culminating product of the evolutionary process!

The place of deep time in the science curriculum is clear, but the methods for getting it there are not simple. Frequently the concept is taught by analogy. For example, Mark Twain likened the Earth's history to the height of the Eiffel Tower, with human history represented by the skin of paint on the top of the highest pinnacle-knob. Teachers often put great creative effort into teaching about the great expanse of time. One teacher has the students in all his classes count dots printed on sheets of paper. When a page is finished, it is taped to the wall. By the day's end all

Rosanne W. Fortner teaches in the School of Natural Resources at Ohio State University, 2021 Coffey Rd., Columbus, OH 43210.

the walls are full, and only 1 million have been counted.

Methodological Contributions

For decades the science curriculum has been teaching people the scientific method—*the* scientific method, translated as how to conduct a proper experiment. Indeed, we can trace many of the major achievements and bodies of knowledge in biology to experiments: Mendelian genetics, the germ theory of disease, biological clocks, recombinant DNA and the like. Of course, there are many instances when experimentation is the preferred means of data acquisition. An observation leads to a hypothesis, data are collected by manipulating some variables while others are held constant, data are analyzed and the hypothesis is accepted or rejected. If Joseph Lister had not experimented to control variables, physicians might still be doing excellent surgery but watching patients die as they did before experiments in aseptic medical procedures. We could be growing mice by Needham's recipe—putting old rags and corn in a barn, whereupon mice arise!

It is a disservice to students, however, to convince them by rote or by example that there is only one method of doing science. Science is characterized by the gathering and analysis of real world data to learn how the world operates. Darwin didn't arrive at his theory of organic evolution by experimentation but by analysis of descriptive data. We would never intentionally experiment to find out what would happen to a population of wild birds if the birds' entire habitat were destroyed; instead we study examples of how habitat loss has affected other bird species and compare those with the circumstances of the species in question.

Data are frequently available to study phenomena we can't control in space or time. "Hands-on" science can be done with such historical and descriptive data from existing sources. For example, one can chart changes in stream macroinvertebrate populations over time or study tombstones to compare the life spans of people at different times in the past.

Historical data continue to make their way into modern science news because studies of the accumulating records of the Earth, both the living and the nonliving parts, assist us in charting trends and making predictions about the future. That living things influence and are influenced by their environment is a basic concept in biology. The "wood cookies" (tree cross-sections) common in life science classrooms are used to find the age of trees and make inferences about their environments. Modern interpretation of tree rings correlates ring width with climate conditions and helps scientists identify recurrent patterns of weather. Other organisms reflect characteristics of their environment in their growth rings as well: tortoises' shell sections, fish scales and otoliths, bands of chemical deposits in reef building corals. Global weather signals may emerge when several biological sources of historic climate data are compared. What we use are data sets of Earth's history, reaching back into deep time and continuing into the future. And because all these data sets are continuously accruing, predictions about tomorrow can be evaluated through monitoring of the changes occurring now. The biological concepts derived from the study of such data are not the results of experimentation but of historical methods used by the Earth scientist.

The changes identified through historical data may be of a time scale of thousands to millions of years, as in evolution, or a time scale of decades to centuries, as in primary succession, or one of days to years, as in tortoise growth. A National Science Foundation-sponsored project at Ohio State University is developing "Secondary Science Curriculum Modules for Global Change Education," which involves the historical method and various time scales.

By interpreting data from animal and plant growth, students can see how the growing conditions of Earth's climate have changed in the recent past. By comparing more recent biological data with ice cores from world glaciers, students see that the glaciers preserve a longer time scale or deeper time, leading them to consider if a recurring trend may be in progress. Another activity uses a time scale on the order of decades, using the historical catch of striped bass in the North Atlantic to explore reasons for the recent lack of fishing success noted in singer Billy Joel's "Downeaster Alexa."

Conceptual Contributions

Increasing applications of satellite imagery in the media, in textbooks and even as art forms show that a genuine "world view" is within our grasp. We can see the Earth as a system with all its parts interconnected. Sophisticated satellites with a wide array of image processing options can observe Earth's biological, geological, chemical and physical aspects and their changes. We receive the satellite information, process it through the imaging software, untangle the data with supercomputers and then share the data with scientists in many parts of the world almost as quickly as it is received. Our communications and data processing capabilities are staggering. The smoke from forest fires in Rondonia, the dried vegetation of drought-stricken California and the productivity of ocean surface waters are all known to us by degree and extent from space platforms many miles above the surface of the planet.

Partly as a result of this world view, scientists from

Fig 1. The 7 basic understandings in the Framework for Earth Systems Education.*

- Earth is unique, a planet of rare beauty and great value.
- Human activities, collective and individual, conscious and inadvertent, are seriously impacting planet Earth.
- The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
- The Earth system is comprised of the interacting subsystems of water, land, ice, air and life.
- Planet Earth is more than 4 billion years old, and its subsystems are continually evolving.
- Earth is a small subsystem of a solar system within the vast and ancient universe.
- There are many people with careers that involve study of Earth's origin, processes and evolution.

*Courtesy of Ohio State University. Complete Framework available in Mayer, V.J. (1991b). A Framework for Earth Systems Education. *Science Activities*, 28(1), 8–9.

all disciplines are beginning to treat the Earth as a system. We prepare global climate models, organize Worldwatch expeditions and report threats to biological diversity in terms of worldwide losses. The nations of the world unite to save whales stuck in the ice and to put out fires in flaming oil wells. Perhaps we have begun to see that ours is a collective future. The more we learn about Earth, the more we come to understand how closely its subsystems—the biosphere, hydrosphere, lithosphere, atmosphere and cryosphere—are intertwined in the production of and response to global changes. What affects one subsystem ultimately affects them all. It has also become more apparent from our views of earth that humankind has been an important agent of change in the past, and probably will continue to be in the future. With the historical data showing our impact in the past, and the signs of our more recent effects, we can more accurately project trends of potential changes on Earth that are attributable to human activity.

Getting Down to Earth

To bring these new technologies and the resulting awareness of connections into the classroom, instructors can use the spectacular satellite images available from the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. An excellent set of diverse images from these agencies is available, with interpretation, as "Oceanography from Space" (NASA 1989). Additional information sources are becoming more accessible as well, in the form of compact disc—"read only" memory (CD-ROM) technology. In a Joint Educational Initiative (JEdI), images and databases from the U.S. Geological Survey, NASA and NOAA have been combined on three 700-megabyte CDs to demonstrate the use of such scientific research tools in the classroom (Sproull 1991). Not only can students examine satellite photos of the Yellowstone fires, they can detect the vegetation differences of biomes through the seasons, model coastal flooding to see the extent of wetland loss and compare ozone levels in their local region with those of Antarctica. Other biology CDs, with widely varying prices and degrees of user-friendliness, include bibliographic databases on "Aquatic Sciences and Fisheries," "Wildlife and Fish Worldwide," the "Life Sciences Collection" and the "Natural Resources Metabase," covering more than 45 government databases. CDs with images as data include "Audobon's Birds of America," complete with bird calls; "Mammals: A Multimedia Encyclopedia," including animations and a game; and "Down to Earth" clip art for desktop publishing. (A list of selected CDs and sources is available from the author.)

Many science teachers are aware of the electronic networking that is bringing classrooms together through the National Geographic KidsNet. That concept is growing in popularity as a means of sharing data about local environmental quality. The Backyard Acid Rain Kit (BARK) from Canada and the Global Rivers Environmental Education Network (GREEN) from the University of Michigan are among new attempts to involve students in the active process of data collection, sharing and analysis, under conditions in which the correct answers to problems are unknown. The student's world view is built from within, as it should be, with relevance first to home and then to the rest of the world.

The interrelationships apparent from the world view technologies must enter the science curriculum at all levels. In the restructuring efforts underway at the national level, many of the implementation models are interdisciplinary ones. A strong focus on understanding the Earth can enrich the science curriculum and give it a relevance that will encourage more student interest in science careers.

Teachers who are ready to get "down to Earth" will be assisted by a Framework for Earth Systems Education, developed and validated by scientists, teachers and science educators nationally (Figure 1). The developers feel that the Framework embodies the big understandings that all students should have about the Earth, whether they are learned in biology classes, environmental education, geography or art. An NSF-sponsored Program for Leadership in Earth Systems Education (PLESE) at Ohio State University (Mayer, in press) is enhancing teachers' abilities to use interdisciplinary studies of Earth to enrich their science curricula as well as to provide a more realistic look at how scientists function. Ultimately, the goal is a future in which decision makers champion the Earth in their political and economic choices.

References

Bar, V. (1989). Children's views about the water cycle. *Science Education*, *73*(4), 481–500.

Fortner, R.W. (1991). *Global change education technology fact sheets* (#10, On-line data sharing networks; #13, CD-ROM; #12. Getting to know—JEdI) Columbus, OH: Ohio State University. (Free with postpaid envelope).

Greene, E.D., Jr. (1990). The logic of students' misunderstanding of natural selection. *Journal of Research in Science Teaching*, *27*(9), 875–885.

Hutton, J. (1795). *Theory of the Earth with proofs and illustrations*. Edinburgh: William Creech.

Jacobson, W.J. & Doran, R.L. (1988). *Science achievement in the United States and sixteen countries*. New York: Teacher's College, Columbia University.

Lyell, C. (1830–1833). *Principles of geology, being and attempt to explain the former changes of the Earth's surface by reference to causes now in operation*. London: John Murray.

Mayer, V.J. (1991a). Earth-systems science. *The Science Teacher*, *58*(1), 34–39.

Mayer, V.J. (1991b). A framework for Earth Systems Education, *Science Activities*, *28*(1), 8–9.

Mayer, V.J. (in press). The role of planet Earth in the new science curriculum. *Journal of Geological Education*.

National Aeronautic and Space Administration. (1989). *Oceanography from space* (photo set with interpretation). Washington, DC: Author.

Sproull, J. (1991). Advanced technologies for the study of Earth systems. *Science Activities*, *28*(1), 19–22.

Notes

THE OHIO STATE UNIVERSITY

Printed on recycled paper