DOCUMENT RESUME

ED 385 446 SE 056 769

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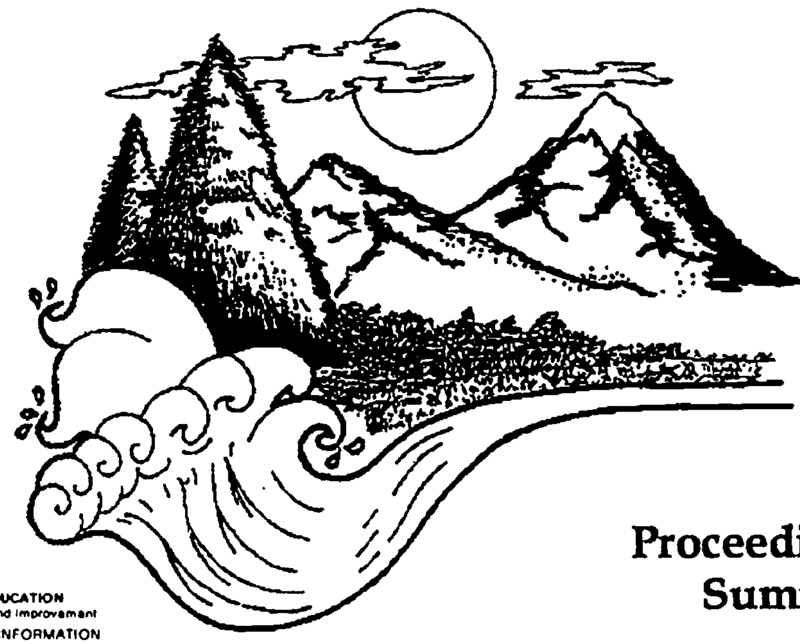
TITLE	High School Symposium for Earth Systems Education (Columbus, Ohio, October 1994). Proceedings and Summary.
PUB DATE	95
NOTE	158p.
AVAILABLE FROM	Ohio State University, School of Natural Resources, ECEI Program, 2021 Coffey Rd., Columbus, OH 43210 ($10).
PUB TYPE	Collected Works - Conference Proceedings (021)
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	Course Descriptions; *Curriculum Development; *Educational Change; Educational Resources; Environmental Education; High Schools; Interdisciplinary Approach; Lesson Plans; *Science Curriculum; Units of Study
IDENTIFIERS	*Earth Systems Education

ABSTRACT

This volume contains the proceedings and summary for the Earth Systems Education high school symposium conducted in October, 1994. Selected participants were invited to contribute papers for inclusion in this volume so that other teachers can see how Earth Systems Education (ESE) looks in practice. The volume also contains the context for ESE in terms of the National Science Education Standards, innovative technologies, and key university developments. The proceedings are presented in the following sections: (1) a symposium overview; (2) restructuring the science curriculum; (3) description of ESE; (4) ESE interface with National Science Education Standards; (5) ESE in context including a teacher's view, ESE at the college level, and ESE in international telecommunications (the GLOBE program); (6) issues in high school science curriculum restructure; (7) participant presentation transcripts; (8) technology support and resources for ESE (includes handouts and additional related information); (9) references cited (contains 14 entries); and (10) appendix. The appendix contains the symposium agenda and participant list, a summary of five published articles concerning the philosophy and history behind ESE, and an annotated bibliography of 50 books and articles useful for assisting teachers in transitions to ESE. Presentations discussing courses include: (1) "Biological and Earth Systems Science (BESS)"; (2) "Earth Systems Regents Course"; (3) "Advance Earth Systems Science and Technology"; (4) "NASA Classroom of the Future"; (5) "Earth Systems Education"; (6) "Vision--Columbus Urban Systemic Initiative"; (7)"Integrated Science"; and (8) "Field Biology." Presentations of units and lessons include: (1) "Case Studies in Environmental Science"; (2) "Interdisciplinary Study of the Cache La Poudre River"; (3) "Integrating ESE into the High School Curriculum"; and (4) "What Affects Ozone Levels?." (LZ)

EARTH SYSTEMS EDUCATION
High School Symposium

October 1994



Proceedings and Summary

Earth Systems Education
OSU School of Natural Resources
2021 Coffey Rd.
Columbus, OH 43210

Proceedings of the High School Symposium for Earth Systems Education

Produced by the
Program for Leadership in Earth Systems Education
under a grant from the National Science Foundation
Division of Teacher Enhancement

The Ohio State University

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printed on recycled paper

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Subject: Symposium Proceedings

Date: May 22, 1995

From: Rosanne Fortner

To: Symposium participants and selected others

Attached is the volume of Proceedings for the Earth Systems Education high school symposium we conducted here in October. One of the culminating activities of the Program for Leadership in Earth Systems Education, it attracted over 40 high school teacher participants from 18 states.

Selected participants were invited to provide papers for inclusion in this volume, so that other teachers can see how Earth Systems Education (ESE) looks in practice. The volume also includes the context for ESE in terms of the National Science Education Standards, innovative technologies, and key university developments.

The book is being sent to leaders in science and environmental education as well as to the participants. A limited number of extra copies of this volume are available from the Earth Systems Education office at $10, which includes shipping and handling. Checks should be made payable to The Ohio State University. The proceedings will be available on ERIC and through the Eisenhower Clearinghouse in the future.

You may also wish to obtain a copy of *Science is a Study of Earth: A Resource Guide for Science Curriculum Restructure*. This loose-leaf volume is the outcome of four years of NSF teacher enhancement and materials review. It includes illustrated copies of published works on ESE, sample activities for infusion at elementary, middle and high school levels, constructivist teaching methods and alternative assessments, resources for interdisciplinary science teaching, and a full-color poster of the seven Earth Systems Understandings. At the present time, teachers requesting a copy on school letterhead may have *Science is a Study of Earth* for $5, the cost of first class shipping and handling. Others may order copies at $20 each from The Ohio State University, address above.

Thank you for your continued interest in and support of Earth Systems Education.

EARTH SYSTEMS EDUCATION
High School Symposium

October 1994

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Earth Systems Education High School Symposium

Overview

On October 13-16, 1994, the Program for Leadership in Earth Systems Education (PLESE) sponsored a symposium at The Ohio State University to focus on models and challenges for implementing ESE and Curriculum restructure at the high school level. Leaders in science and science education on the national level were invited to discuss trends with implications for the curriculum, and teachers implementing a systems approach in high school science shared their methods and materials. Conference participants were supported through a National science Foundation grant Teacher Enhancement Division (NSF #TPE-8955248).

The goal of the symposium was to provide professional support for teachers attempting to restructure the science curriculum in high school. Specific objectives were to

1) legitimize change in light of national trends and standards
2) focus on ESE as a model for science curriculum restructure
3) provide opportunities for networking with other science teachers and education leaders
4) offer science and technology updates for classroom users
5) introduce support systems in science, education, resources, and such.

This report serves as the Proceedings volume for the Symposium but also offers additional resources requested by the participating teachers. The report supplements *Science is a Study of Earth: A Resource Guide for Science Curriculum Restructure* (Mayer, Fortner & Hoyt, eds., 1995), the outcome volume for the five years of PLESE.

Restructuring the Science Curriculum

Numerous efforts are underway in the 1990s to restructure science education in response to growing concerns that the existing "layer cake" (discipline-ordered) approach to science lacks relevance to students, prepares them poorly in life skills that demand science literacy, leaves US students lagging on standardized international tests of science knowledge, and ignores or perhaps even perpetuates naive conceptions in science. The primary efforts to change these patterns have emerged from and had the support of national organizations in science and education:

• Project 2061 is a program of the American Association for the Advancement of Science (AAAS). Through its book *Science for All Americans* (AAAS, 1989) and the associated science discipline booklets detailing background information, this project identified science concepts that every high school graduate in the United States should know. Major contributions of this effort include the idea that "less is more," or a curriculum that deals with fewer concepts in greater detail is preferred over the traditional vocabulary-laden mini-college courses common in US secondary schools. Follow-up work through selected school districts has produced several models for implementing the curriculum changes implied by 2061, and has resulted in a set of *Benchmarks* for Science Literacy (AAAS, 1993)for designing the course sequences and gauging the progress of students in science through their school careers.

• Scope, Sequence and Coordination (NSTA, 1992) was an effort of the National Science Teachers Association to outline a secondary science curriculum for grades7-12 that coordinated the science disciplines and focused on major concepts that would be revisited at various grade levels in progressing degrees of complexity and scale. A book entitled *The Content Core* related NSTA's conception of appropriate subject matter for science, and a companion piece, *Relevant Research,* offered a theoretical and research-based rationale for curriculum restructure of this nature. These efforts were supported by NSF and NSTA, but since the conclusion of NSF support the project has not been able to attract substantive national attention to implementation plans. NSTA now works with publishers to develop textbooks that the organization hopes will facilitate curriculum restructure and integration.

• NSF Systemic Initiative grants to states, cities, and rural areas have been providing millions of dollars in matching support for systemic change in science education on state to local scales. It is too early to determine if the combination of these efforts nationally will result in strengthened programs that are considerably different from the traditional curriculum, but they have certainly had an opportunity to involve more teachers in their implementation than those national projects that to date have primarily sought demonstration sites.

Earth Systems Education

In much of the discussion of what science belongs in the curriculum for all students, the Earth sciences have been slighted (Mayer, et al., 1992). In response to this, and with the firm belief that all of science is involved with understanding planet Earth, the Earth Systems Education (ESE) efforts have emerged as a grassroots mechanism for internally changing what is taught in science K-12.

Earth Systems Education takes its name from NASA's vision of Earth System Science (Earth System Science Committee, 1988), an idea that all of Earth's subsystems, the hydrosphere, lithosphere, atmosphere and biosphere, interact and change over time in ways that preclude study of one without consideration of the others. This is particularly true in the ways those subsystems respond to human activities and in return, impact them. Integration of the sciences, then, is key to understanding all Earth characteristics and processes. ESE is education's approach to Earth System Science. All of science is seen as a means of understanding Earth (Mayer, 1991).

Earth Systems Education is guided by a framework of seven Earth Systems Understandings (page 5) developed by a core advisory group of scientists, teachers, and science educators. The Understandings incorporate science process, subsystem interactions, the construct of change over time, and Earth's place as a subsystem of the Universe. They also incorporate reasons for the study of Earth: aesthetics and values, careers and interests, and the responsibility for stewardship.

The goal of Earth Systems Education is to infuse Earth systems concepts throughout the curriculum at all grade levels, K-college. The approach taken by leaders in this effort has been to rely on teachers, for experience demonstrates that teachers can implement lasting change by believing in the need and becoming part of the process. The top-down approaches of major curriculum restructure programs have great visibility and political power because of the entities sponsoring them, but unless teachers accept the proposed changes and their role in those changes, the efforts will fall short of their potential.

ESE, then, has been propelled through teacher enhancement programs both at the origin (The Ohio State University and the University of Northern California) and in other parts of the country. Summer workshops, leadership opportunities for teachers, and networking have begun to result in grassroots changes in participants' schools. As part of the ESE efforts in central Ohio, the founding home of the program, high school teachers in Worthington City Schools have implemented complete curriculum restructure in grades 9-10 as the required two-year course, Biological and Earth Systems Science. With support from the Eisenhower Mathematics and Science Education Act, teacher teams in ten other central Ohio school districts have been introduced to ESE concepts and methods. A report describing BESS is included in the presentation summaries, and a separate volume on its evaluation through 1994 is available from the Earth Systems Education Office.

ERIC CSMEE Digest

Clearinghouse for Science, Mathematics, and Environmental Education EDO-SE-93-2 March 1993

Earth Systems Education

Victor J. Mayer

National concerns about the quality and effectiveness of science teaching have resulted in several major efforts directed at restructuring the nation's curriculum, including Project 2061 of the American Association for the Advancement of Science (AAAS, 1989) and the Scope, Sequence, and Coordination project of the National Science Teachers Association (NSTA, 1992). A third effort is the Earth Systems Education program centered at The Ohio State University and the University of Northern Colorado (Mayer, editor, 1992). Its philosophy and approach to science content is consistent with the better-known projects but differs in significant respects, especially in its focus on planet Earth.

Understanding Planet Earth

Over the past two decades there have been tremendous advances in the understanding of planet Earth in part through the use of satellites in data gathering and super computers for data processing. As a result, Earth scientists are reinterpreting the relationships among the various science sub-disciplines 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 Systems Science Committee, 1986). These advances also prompted the organization of a conference of geoscientists and educators in April, 1988, to consider their implications for science curriculum renewal. The 40 scientists and educators, including many scientists from the agencies responsible for the Bretherton Report, developed a preliminary framework of four goals and ten concepts about planet Earth that they felt every citizen should understand (Mayer and Armstrong, 1991). Through subsequent discussions with teachers and Earth science educators at regional and national meetings of the NSTA, a renewed concern emerged for a more adequate treatment of planet Earth in the nation's science curriculum.

Infusion through Teacher Enhancement

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 program was designed to infuse more content regarding the modern understanding of planet Earth into the nation's K–12 science curricula.

In preparation for PLESE, a planning committee composed of ten teachers, curriculum specialists, and geoscientists met in Columbus, Ohio in May, 1990, to develop a conceptual framework to guide the program. Preliminary work included the analysis of the Project 2061 report for content related to Earth systems. The committee used this analysis combined with the results of the 1988 conference to develop a framework consisting of seven understandings. This Framework for Earth Systems Education provided a basis for the PLESE teams to construct resource guides and to select teaching materials for use in infusing Earth systems concepts into the science curriculum in their areas (Mayer, 1991). The program has worked with over 180 teachers in three member teams including an upper elementary teacher, a middle school teacher, and a high school teacher during three-week long summer programs. These teams have conducted Earth Systems awareness workshops in their states, communities, and at national NSTA conferences. During the summer of 1993, selected participants prepared resource guides for use at each of the three grade levels.

Earth Systems Education Framework

The PLESE Planning Committee intentionally arranged the understandings of the Earth Systems Education Framework into a sequence (Mayer, 1991). The first emphasizes the aesthetic values of planet Earth as interpreted in art, music, and literature. By focusing on students' feelings towards the Earth systems, the way in which they and others experience and interpret them, students are drawn into a systematic study of their planet. An aesthetic appreciation of the planet leads the student naturally into a concern for the proper stewardship of its resources: the second understanding of the framework (Mayer, 1990). 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. In learning how the subsystems function, students must master basic physics, chemistry, and biology concepts. The last understanding deals with careers and vocations in science, bringing the focus once again back to the immediate concerns and interests of the student (Fortner, editor, 1991).

Earth Systems Education and Science Curriculum Restructuring

Teachers using the Framework to develop their resource guides saw its application for the development of integrated science curricula, an objective of both Project 2061 and NSTA's SS&C effort. What could be more natural than developing K–12 science curricula using the subject of all science investigations—planet Earth—as the unifying theme? Any physical, chemical, or biological process that citizens must understand to be scientifically literate can be taught in the context of its Earth subsystem. That is the thought that has guided a number of teachers and curriculum specialists in considering the implications of Earth Systems Education for the nation's science curriculum reform efforts (Mayer, et al, 1992).

The Earth Systems Education effort also seeks to implement a more holistic philosophy of the nature of science into what has been criticized as a reductionist curriculum. Stephen Gould, occupant of the Agassi Chair of Paleontology at Harvard University has characterized the nature of science as it is presented in today's schools in the United States:

> 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 phylogentic history, or biogeography—where experiment and repetition have limited application to systems in total—they can only conclude that something beneath science, something merely "descriptive," lies before them (Gould, 1986).

The commonly held image of science that is reinforced in our classrooms is that of controlled laboratory experiments conducted by a balding man wearing a white lab coat. Basic to the Earth Systems Education approach is to give a more comprehensive understanding of the nature of science and its intellectual processes including the historical descriptive approaches commonly used by the earth and biological sciences (Mayer, et al, 1992).

Earth Systems Education efforts also take a constructivist approach to learning both in workshops conducted by the staff and in the curriculum restructuring efforts. Most learning goes on in small collaborative groups working on real issues and problems dealing with the Earth System. Another basic tenant is that curriculum restructuring must be a "grass-roots" effort. Teachers are the curriculum developers. Other individuals, be they university professors, professional association staff, state or local level administrators, serve a facilitating function. The curriculum itself must be developed and therefore owned by the teachers who teach it (Mayer, et al, 1992).

Earth Systems Education Projects

Several projects are underway to test aspects of Earth Systems Education. The oldest and furthest along is the implementation of an integrated Biological and Earth Systems (BESS) science sequence into the high schools in the Worthington (OH) School District (Fortner, et al, 1992). It is a required sequence replacing both Earth science at the 9th grade and Biology at 10th. The sequence is organized around basic Earth systems issues such as resource supply, global climate change, and deforestation. The program incorporates collaborative learning and problem-solving techniques as major instructional strategies. Current technology is also used including on-line and CD-ROM databases for accessing current scientific data for use in course laboratory instruction. Ten additional Ohio and New York school systems are now studying the BESS program for its implications for their curriculum restructuring efforts.

Other efforts at elementary, middle, and high school levels are now underway in school districts in New York, Colorado, Ohio, Oregon, and Illinois.

Conclusion

The time appears to be ripe for the first total restructuring of the science curriculum since the current high school course sequence was established in the late 1800s. The dramatic changes that have taken place in science, in the understanding of how science is learned, in the evolving demands of technology, and in the pressures they place on our environment require this restructuring. Earth Systems Education offers an effective strategy. As a first step, it infuses planet Earth concepts into all levels of the K–12 science curriculum. In 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 provides a basis for the recruitment of talent into science and technology careers.

References

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

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

Fortner, R. W., (Ed.). (1991). Earth systems education [Special issue]. *Science Activities, 28*(1).

Fortner, R. W. (1992). Down to earth biology: A planetary perspective for biology curriculum. *The American Biology Teacher, 54*(2), 76-79.

Fortner, R. W., et al. (1992). Biology and earth systems science. *The Science Teacher, 59*(9), 32-37.

Gleick, J. (1987). *Chaos: Making a new science.* NY: Penguin Books.

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

Mayer, V. J. (1988). *Earth systems education: A new perspective on planet Earth and the science curriculum.* Columbus, OH: The Ohio State University.

Mayer, V. J. (1989). Earth appreciation. *The Science Teacher, 56*(3), 22-25.

Mayer, V. J. (1990). Teaching from a global point of view. *The Science Teacher, 57*(1), 26-30.

Mayer, V. J. (1991). Earth-system science: A planetary perspective. *The Science Teacher, 58*(1), 31-36.

Mayer, V. J. (1991). Framework for Earth systems education. *Science Activities, 28*(1), 8-9.

Mayer, V. J. (Ed.). (1992). *Earth systems education: Origins and opportunities.* Columbus, OH: The Ohio State University.

Mayer, V. J., & Armstrong, R. 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.

Mayer, V. J., et al. (1992). The role of planet Earth in the new science curriculum. *Journal of Geological Education, 40*(1), 66-73.

The National Science Teachers Association. (1992). *Scope, sequence, and coordination of secondary school science: The content core.* Washington, DC: Author.

OERI This digest was funded by the Office of Educational Research and Improvement, U.S. Department of Education under contract no. RI-88062006. Opinions expressed in this digest do not necessarily reflect the positions or policies of OERI or the Department of Education.

ERIC Educational Resources Information Center. The nationwide information system initiated in 1966 by the U.S. Department of Education. ERIC is the largest and most frequently used database in the world.

SE 053 470

FRAMEWORK FOR EARTH SYSTEMS EDUCATION

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 of all cultures through literature and the arts.
- Human appreciation of 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, affect Earth Systems.*

- 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.*

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

Understanding #4: *The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.*

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

Understanding #5: *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 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 and interests that involve study of Earth's origin, processes, and evolution.*

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

The development of this framework started in 1988 with a conference of educators and scientists and culminated in the Program for Leadership in Earth Systems Education. It is intended for use in the development of integrated science curricula. The framework represents the efforts of some 200 teachers and scientists. Support was received from the National Science Foundation, The Ohio State University and the University of Northern Colorado.

For further information on Earth Systems Education contact the Earth Systems Education Program Office, School of Natural Resources, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210.

ESE and the National Standards for Science Education

National Science Education Standards (NCSESA, 1994 draft) are the National Academy of Science's attempt to develop guidelines for science curriculum restructure and systemic change. Not only do the National Standards include science content standards that express need for integration of disciplines, fewer topics in greater depth, and articulation across grade levels, they also provide guidelines for restructuring the teaching of science, the environment for science in schools, and assessment of science learning. The Standards are emerging in 1995 as the most comprehensive and perhaps most esteemed of the restructure guidelines.

As the United States prepares to adopt National Standards, Earth Systems educators find that their content and methods mesh closely with the intent and the letter of the proposed standards. Integration of science disciplines (Understanding #4) is stressed in the Standards, as is the role of citizens in issues of science and society (ESU #2). Laboratory experiences include more opportunity to involve students in historical/descriptive research designs, as well as the more traditional use of "the" scientific (experimental) method (ESU #3). Use of new technological tools is encouraged, not just in the form of classroom computers but as remotely sensed data, information searching tools and the like (ESU #3). Content sections specifically labeled as Earth Systems broaden the traditional Earth Science content to include interactions of Earth with living things, changes of the Earth over time, physical/chemical processes, and characteristics of Earth as a planet (ESUs 5-6).

As for classroom methodology, the Standards section on the environment for teaching specifically identifies collaborative/cooperative learning techniques as a method for bringing science into the social process. This helps students learn how scientists consult each other's work as it applies to interdisciplinary problems (Mayer, Fortner & Hoyt, in review).

To bring the symposium participants up to date on the progress of the National Standards as of October 1994, Dr. Harold Pratt, who served on the committee drafting the Standards, spoke to the group. His information is summarized in the pages that follow.

National Science Education Standards

Discussion Summary

National Research Council
National Committee on Science Education Standards and Assessment (NCSESA)

September 12, 1994

What Are National Education Standards?

National Science Education Standards offer a coherent vision of what it means to be scientifically literate. The standards describe what all students must understand and be able to do as a result of their cumulative learning experiences. The standards also provide criteria for judgments regarding systems, programs, teaching, and assessment which can provide opportunities for all students to learn science in ways that are aligned with the standards.

The statement, "All students," reflects the social commitment that standards apply to students regardless of background (gender, ethnicity, economic condition), circumstance, or ambition.

"National" means a nationwide agreement, not a federal mandate, on what defines successful science learning and the school practices that support that learning. National standards do not define a national curriculum and do not suggest a form of national standardization of an actual curriculum.

The *National Science Education Standards* are organized in five categories.

- SCIENCE SYSTEM STANDARDS
  specify the support systems and resources needed to provide all students the opportunity to learn science. They include the criteria that each component and/or level of the education system as well as the whole system must meet and they define how systems function to support the vision of science education presented in the *National Science Education Standards*.

- SCIENCE PROGRAM STANDARDS
  specify the nature, design, and consistency of the school and district science program that affect students learning science.

- SCIENCE TEACHING AND PROFESSIONAL DEVELOPMENT STANDARDS
  specify the criteria for the exemplary practice of science teaching. Such teaching provides students with experiences that enable them to achieve the understanding and ability of the Science Content Standards. Teaching Standards also describe the knowledge and skills that are the foundation of such practice and the professional development of science teachers.

- SCIENCE ASSESSMENT STANDARDS
  specify criteria for assessing and analyzing students' attainments in science and the opportunities to learn which school science programs afford students.

- SCIENCE CONTENT STANDARDS
  specify expectations for the development of: proficiency in conducting inquiry including the use of scientific modes of reasoning, and the ability to apply and to communicate scientific knowledge; scientific understanding of concepts, laws, theories and models; understanding of the interdependent relationship of science and technology; and understanding of the influence of science on societal issues, both contemporary and historical.

Science education standards are guided by these principles:

- All students, regardless of gender, cultural or ethnic background, physical or learning disabilities, future aspirations, or interest and motivation in science should have the opportunity to attain high levels of scientific literacy.
- The science that all students are expected to learn is defined so that students have sufficient time to develop a deep understanding of essential scientific ideas rather than superficial acquaintance with many isolated facts. All students can attain science knowledge with understanding.
- Learning science is an active process in which all students engage. In science, students ask questions, construct explanations of natural phenomena, test those explanations in many different ways and communicate their ideas to others.
- Science in school will reflect the intellectual tradition -- modes of inquiry, rules of evidence, and ways of formulating questions -- that characterizes the practice of contemporary science.
- Science education reform is a systemic process in which all persons have roles and the responsibility to change.

National Science Education Standards Outline

'Call to Arms'

Prologue

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System Standards

The System Standards are criteria for judging the performance of the parts of the science education system responsible for providing schools with the financial and intellectual resources necessary to achieve the vision contained in the program, teaching, assessment, and content standards.

System Standards include:

- **Common Vision.** Policies that influence the practice of science education must be consistent with the program, teaching, assessment, and content standards while allowing for adaptation to local circumstances;

- **Coordination Across the System.** Policies should be coordinated within and across agencies, institutions, and organizations;

- **Continuity.** Policies need to be sustained over sufficient time to provide the continuity necessary to bring about changes required by the Standards;

- **Resources.** Policies must be supported with resources;

- **Equity.** Science education policies must be equitable;

- **Unanticipated Effects.** All policy instruments must be reviewed for possible unintended effects on the classroom practice of science education; and

- **Individual Responsibility.** Responsible individuals should take the opportur.ty afforded by the standards-based reform movement to achieve the new vision of science education portrayed in the Standards.

Program Standards

The Program Standards provide criteria for judging the quality of and conditions for school science programs. The program standards focus on issues at the school and district level that relate to opportunities for students to learn and opportunities for teachers to teach science as described in the Standards. The program standards and the system standards address issues related to the vision, support, and integration of the teaching, content, and assessment standards. The program standards address these issues from a point of view close to the experiences of students -- the classroom, school, and district levels. The system standards address them from the point of view farthest from students -- the national, state, community, and the district levels.

Program Standards include:

- **Consistency in Program.** All elements of the K-12 science program must be consistent with the standards and with one another and be articulated within and across grade levels to meet a clearly stated set of goals. An effective science program encompasses the elements described below.

- ◊ A set of clear goals and expectations for students is used to guide the design, implementation, and assessment of all elements of the science program.
- ◊ A curriculum framework is used to guide the selection and development of units and courses of study.
- ◊ Teaching practice is consistent with the goals and curriculum framework.
- ◊ Assessment policies and practices are aligned with the goals, student expectations, and curriculum frameworks.
- ◊ Support systems and formal and informal expectations of teachers are aligned with the goals, expectations of students, and curriculum frameworks.
- ◊ Responsibility is clearly defined for determining, supporting, and maintaining all elements of the science program.

- ♦ **Curriculum.** The curriculum in science for all students in grades K-12 should contain the aspects described below.
  - ◊ All the content standards should be included and should be embedded in a variety of curriculum patterns that are developmentally appropriate, interesting, and relevant to students' lives.
  - ◊ Inquiry should be emphasized as a tool for learning science.
  - ◊ The curriculum should connect to other school subjects.

- ♦ **Mathematics and Science.** The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics overall.

- ♦ **Resources.** The K-12 science program should give students access to appropriate and sufficient resources including time, materials and equipment, space, teachers, and community.
  - ◊ Time is a major resource in a science program.
  - ◊ Conducting scientific inquiry requires that students have easy and frequent opportunities to use a wide range of equipment, materials, supplies, and other resources for experimentation and direct investigation of phenomena.
  - ◊ Collaborative inquiry requires space as well as time.
  - ◊ The most important resource is personnel.
  - ◊ Good science programs require access to the world beyond the classroom.

- ♦ **Equity and Excellence.** All students in the K-12 science program must have equitable access to opportunities to achieve the *National Science Education Standards.*
  - ◊ All students, regardless of sex, cultural or ethnic background, physical or learning disabilities, future aspirations, or interest in science, should have the opportunity to attain high levels of science literacy. By adopting this principle, Standards prescribe the inclusion of all students in challenging science learning opportunities and define a level of understanding that all students should achieve.

- ◊ Not only is science education for all students, but all of the understandings and abilities described in the content standards should be achieved by all students. This is the principle of excellence. The standards describe expectations of achievement.

- ♦ **Schools as Communities of Learners.** Schools must be communities that encourage, support and sustain teachers as they implement an effective science program.
  - ◊ Schools must demonstrate colleagueship, openness, and trust, as well as explicitly support reform efforts.
  - ◊ Regular time must be provided for and teachers encouraged to discuss, reflect, and conduct research around science education reform.
  - ◊ Regular time and opportunities within the working day must be provided for teachers of science to engage in professional growth.
  - ◊ Teachers need support in creating and participating in networks of reform.
  - ◊ An effective leadership structure must be in place that includes teachers.

Teaching and Professional Development Standards

The National Science Standards for Teaching and the Professional Development of Teachers are organized into two sections. The first focuses on what teachers do and is called the "Standards for Science Teaching." The second focuses on how teachers develop professional knowledge and skill and is called "Standards for the Professional Development of Teachers of Science." Together the standards present a broader and deeper view of the science that is fundamental and useful to an informed citizenry; the conviction that scientific inquiry is at the heart of science and science learning; and the need for all students to leave school literate in science.

Teaching Standards include:

- ♦ **Planning the Science Program.** Teachers of science will plan an inquiry-based science program for their students. In doing this, they:
  - ◊ develop a framework of long- and short-term goals for their students,
  - ◊ select science content and adapt and design curriculum to meet the particular interests, knowledge, skills and experiences of their students,
  - ◊ determine teaching strategies that support the development of student understanding and nurture a community of science learners, and
  - ◊ work with colleagues within and across disciplines and levels.

- ♦ **Guiding and Facilitating Learning.** Teachers of science will guide and facilitate science learning. In doing this they:
  - ◊ interact with their students to focus and support their inquiries,
  - ◊ orchestrate discourse among students about scientific ideas,
  - ◊ challenge students to take responsibility for their own work and also to work collaboratively,
  - ◊ recognize and respond to student diversity and encourage all students to participate fully in science learning, and

◊ encourage and model the skills of scientific inquiry as well as the curiosity, openness to new ideas, and skepticism that characterizes science.

- **Assessing Learning and Teaching.** Teachers of science will engage in ongoing assessment of their teaching and of student learning. In doing this, they:
  - ◊ systematically gather data on their students and their development,
  - ◊ analyze assessment data to guide teaching,
  - ◊ guide students in self-assessment, and
  - ◊ use student data, observations of teaching, and interactions with colleagues to reflect on and improve practice.

- **Designing and Managing the Physical Environment.** Teachers of science will design and manage a learning environment that provides students with the time, space, and resources needed for learning science. In doing this, they:
  - ◊ structure the time available so that students are able to engage in extended investigations,
  - ◊ generate a setting for student work that is flexible and supportive of science inquiry,
  - ◊ ensure a safe working environment,
  - ◊ make the available science tools, materials, print, and technological resources accessible to students,
  - ◊ identify and use resources outside the school, and
  - ◊ engage students in designing the environment.

- **Building Learning Communities.** Teachers of science will develop communities of science learners that reflect the intellectual rigor of scientific inquiry, the attitudes, and the social values conducive to science learning. In doing this, they:
  - ◊ display and demand a respect for and valuing of the ideas, skills, and experiences of all students,
  - ◊ give students a significant voice in decisions about the content and context of their work, and require students to take significant responsibility for the learning of all members of the community,
  - ◊ nurture collaboration,
  - ◊ structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse, and
  - ◊ model and emphasize the skills, attitudes, and values of scientific inquiry.

- **School Planning.** Teachers of science will be active participants in the ongoing planning and development of the school science program. In doing this, they:
  - ◊ plan and develop the school science program,
  - ◊ have a voice in decisions concerning the allocation of time and other resources to the science program, and
  - ◊ plan and implement professional growth and development strategies for themselves and their colleagues.

Professional Development Standards include:

- **Learning Science Content.** The professional development of teachers of science requires learning science content through the perspectives and methods of inquiry. Science learning experiences for teachers should:
  - ◊ involve teachers in actively investigating scientific phenomena, interpreting their results, and making personal sense of their findings consistent with currently accepted scientific understanding,
  - ◊ address issues, events, problems, or topics significant in science and of interest to participants,
  - ◊ introduce teachers to scientific literature, media and technological resources that expand their science knowledge and their ability to access further knowledge,
  - ◊ build on the teacher's existing science knowledge, skills, and attitudes,
  - ◊ incorporate ongoing reflection on the process and outcomes of understanding science through inquiry, and
  - ◊ encourage and support teachers to work together.

- **Learning to Teach Science.** Professional development of teachers of science requires the integration of a knowledge of science, learning, pedagogy, and students, and the application of this understanding to science teaching. Learning experiences for teachers of science must:
  - ◊ connect and integrate all aspects of science and science education,
  - ◊ use actual classroom experience to illustrate and model effective science teaching,
  - ◊ address teachers' developmental needs and build on their existing knowledge of science content, teaching, and learning, and
  - ◊ use strategies of inquiry, reflection, interpretation of research papers, modeling, and guided practice to build understanding and skill in science teaching.

- **Learning to Learn.** The professional development of teachers of science should enable teachers to build the knowledge, skills, and attitudes needed to engage in life-long learning. Science learning experiences for teachers must:
  - ◊ provide regular, frequent opportunities for individual and collegial examination and reflection on classroom and institutional practice,
  - ◊ provide opportunities for teachers to receive feedback about their teaching and to understand, analyze, and apply that feedback to improve their practice,
  - ◊ provide opportunities for teachers to learn and use various tools and techniques for self and collegial reflection, such as peer coaching, portfolios, and journals,
  - ◊ support the sharing of teacher expertise by preparing and using mentors, teacher advisors, coaches, lead teachers, and resource teachers to provide professional development opportunities,
  - ◊ provide opportunities to know and have access to existing research and experiential knowledge, and
  - ◊ provide opportunities to learn and use the skills of research to generate new knowledge.

- **Developing Professional Development Programs.** Pre-service and in-service professional development programs for teachers of science must be coherent and integrated. Quality programs are characterized by:
  - ◊ clear and shared goals that are based on a vision of science learning, teaching, and teacher development congruent with the *National Science Education Standards*,
  - ◊ integration and coordination of the components so that understanding and skills can be built over time, reinforced continuously, and practiced in a variety of situations,
  - ◊ options that recognize the developmental nature of teacher professional growth and individual and group interests, as well as the needs of teachers who have varying degrees of experience, professional expertise, and proficiency,
  - ◊ collaboration among the people involved in the programs, including teachers, teacher educators, teacher developers, scientists, school administrators, policy makers, and business people-and respect for the unique perspectives and expertise of each,
  - ◊ recognition of the history, culture, and organization of the school environment, and
  - ◊ continuous program assessment that captures the perspectives of all those involved, uses a variety of strategies, both formal and informal, focuses on both the process and impact of the program, and feeds directly into the program improvement and evaluation.

Assessment Standards

Science Assessment Standards are criteria against which to judge the quality of assessment practices used to measure student attainment and the quality of opportunities provided students to learn science. The assessment standards can be used as guides in developing assessment practices and policy. They are statements of principle identifying essential characteristics of exemplary assessment practices.

Assessment Standards include:

- **Coordinating Assessments with Purposes.** Assessments are consistent with the decisions that they are designed to inform.
  - ◊ Assessments are deliberately designed.
  - ◊ Assessments have explicitly stated purposes.
  - ◊ The relationship between decisions and data is clearly stated.
  - ◊ Assessments' procedures are internally consistent.

- **Measuring Student Attainment and Opportunity to Learn.** The achievement data collected focuses on the science content that is most important for students to learn.
  - ◊ Data collected reflect the complexity of the National Science Education Content Standards and measure student ac' ievement of each and all of the dimensions described in those standards.

Opportunity to learn data collected focuses on the most powerful indicators of students' opportunity to learn.

- ◊ Data collected reflects the essential indicators of opportunity to learn as they are described in the National Science Education Teaching, Program, and System Standards.

Equal attention is given to the assessment of opportunity to learn and to the assessment of student attainment.

- ♦ **Matching Technical Quality of Data with Consequences.** The technical quality of data collected is well matched to the consequences of the decisions and actions taken on the basis of the interpretation of those data.
  - ◊ The feature of student attainment or opportunity to learn that is claimed to have been measured was actually measured.
  - ◊ Assessment tasks are authentic.
  - ◊ Time intervals for data collection reflect the time dimension implied in what is being measured.
  - ◊ An individual student's performance is the same on two or more tasks that claim to measure the same aspect of student attainment.
  - ◊ Students have adequate opportunity to demonstrate their achievements.
  - ◊ Tasks and methods provide data that are sufficiently stable to lead to the same decisions if utilized at different times.

- ♦ **Avoiding Bias.** Assessment practices are fair.
  - ◊ Large scale assessments use statistical techniques to identify differential performance among sub-groups of the population assessed that signal potential bias.
  - ◊ Males and females of different racial and ethnic backgrounds have been included in the development of large scale assessments.
  - ◊ Assessment tasks have been reviewed for the use of stereotypes, for assumptions that reflect the perspectives or experiences of a particular group, for language which may be offensive to a particular group and for other features which may distract students from the intended task.
  - ◊ Assessment tasks are modified appropriately to accommodate the needs of students with physical disabilities or limited English proficiency.
  - ◊ Assessment tasks are set in a variety of contexts, engaging to students with different interests and experiences.
  - ◊ Assessment tasks do not assume the perspective or experience of a particular gender, racial, or ethnic group.

- ♦ **Making Sound Inferences.**
  - ◊ When making inferences from an assessment, explicit reference is made to the assumptions on which inferences are based.

Content Standards

There are eight categories of content standards.

Science as Inquiry
Physical Science
Life Science
Earth and Space Science
Science and Technology
Science in Personal & Social Perspectives
History and Nature of Science
Unifying Concepts and Processes

The first seven categories have standards for grade levels K-4, 5-8, and 9-12. The final category crosses all grade levels.

The content described in the standards does not represent a science curriculum. Curriculum includes not only the content, but also the structure, organization, balance, and presentation of the content. The selection of the fundamental understanding reflected in these standards is based on the following criteria: a) it represents a central scientific idea and organizing principle, b) it has rich explanatory power, c) it guides fruitful investigations, d) it applies to situations and contexts common to everyday experiences, e) it can be linked to meaningful learning experiences, and f) it is developmentally appropriate for students at the grade level specified.

Science as Inquiry should be recognized as a basic and controlling principle in the ultimate organization of and experiences in students' science education. This standard on inquiry includes both the ability to do inquiry and to understand inquiry.

As a result of activities in grades K-4, all students should develop:
- abilities of scientific inquiry, and
- an understanding about scientific inquiry.

As a result of inquiry-oriented activities in grades 5-8, all students should develop:
- abilities of scientific inquiry, and
- an understanding about scientific inquiry.

As a result of inquiry-oriented activities in grades 9-12, all students should develop:
- abilities of scientific inquiry, and
- an understanding about scientific inquiry.

Physical, life, and earth and space science express the primary subject matter of science. Science subject matter focuses on those science concepts, principles, and theories that are fundamental for all students to know and be able to use.

Physical Science

As a result of activities in grades K-4, all students should develop an understanding of:

- properties of objects and materials,
- position and motion of objects, and
- heat, light, electricity and magnetism.

As a result of activities in grades 5-8, all students should develop an understanding of:

- properties of matter,
- motions and forces, and
- transformations of energy.

As a result of activities in grades 9-12, all students should develop an understanding of:

- the structure of atoms,
- structure and properties of matter,
- chemical reactions,
- forces and motion,
- conservation of energy,
- the increase in disorder, and
- interactions of energy and matter.

Life Science

As a result of their activities in grades K-4, all students should develop an understanding of:

- needs and characteristics of organisms,
- life cycles of organisms, and
- relationship between organisms and environments.

As a result of their activities in grades 5-8, all students should develop an understanding of:

- structure and function in living systems,
- reproduction and heredity,
- regulation and behavior,
- populations and ecosystems, and
- diversity and adaptations of organisms.

As a result of their activities in grades 9-12, all students should develop an understanding of:

- the diversity of organisms,
- the cell,
- heredity,
- nervous system and the behavior of organisms,
- interdependence of organisms in the biosphere,
- matter, energy, and organization of living systems, and
- mechanisms and consequences of biological evolution.

Earth and Space Science
As a result of their activities in grades K-4, all students should develop an understanding of:
- properties of earth materials, and
- objects in the sky.

As a result of their activities in grades 5-8, all students should develop an understandings of:
- Structure of the Earth System,
- Earth's history, and
- Earth in the Solar System.

As a result of their activities in grades 9-12, all students should develop an understanding of:
- energy in the Earth system,
- geochemical cycles,
- origin and evolution of the earth system, and
- origin and evolution of the Universe.

The **Science and Technology** standard establishes useful connections between the natural world and the designed world and offers essential decision-making abilities.

As a result of activities in grades K-4, all students should develop:
- abilities of technological design, and
- understanding about science and technology.

As a result of activities in grades 5-8, all students should develop:
- abilities of technological design, and
- understanding about science and technology.

As a result of activities in grades 9-12, all students should develop:
- abilities of technological design, and
- understanding about science and technology.

The standard on **Science in Personal & Social Perspectives** connects students with their social and personal world. It helps them develop understandings that enable them to fulfill their obligations as citizens.

As a result of activities in grades K-4, all students should develop an understanding of:
- personal health,
- characteristics and changes in populations,
- types of resources,
- changes in environments, and
- science and technology in local challenges.

As a result of activities in grades 5-8, all students should develop an understanding of:
- personal and environmental health,
- populations, resources, and environments,

- natural hazards,
- risks and benefits, and
- science and technology in society.

As a result of activities in grades 9-12, all students should develop an understanding of:
- personal and community health,
- population growth,
- natural resources,
- environmental quality,
- natural and human-induced hazards, and
- science and technology in local, national, and global changes.

The standard on the **History and Nature of Science** includes an understanding of the nature of science and uses history in school science programs to clarify different aspects of scientific inquiry, science in society, and the human aspects of science.

As a result of activities in grades K-4, all students should develop an understanding of:
- science as a human endeavor.

As a result of activities in grades 5-8, all students should develop an understanding of:
- science as a human endeavor,
- nature of science, and
- history of science.

As a result of activities in grades 9-12, all students should develop an understanding of:
- science as a human endeavor,
- nature of scientific knowledge, and
- historical perspectives.

The **Unifying Concepts and Processes** standard provides students with powerful ideas that help them understand the natural world. These conceptual and procedural schemes are integral to students' science learning experiences. The understanding and abilities associated with this standard should be developed over the entire K-12 continuum.

All students should develop an understanding of and ability to use the following concepts and processes:
- order and organization,
- evidence, models, and explanation
- changes and measurement,
- evolution and equilibrium, and
- form and function.

How to Reach Us

To receive more information on the science education standards, or to be placed on the mailing list for future documents please contact:

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We look forward to hearing from you!

The National Science Education Standards Project is funded by the U.S. Department of Education, the National Science Foundation, the National Aeronautics and Space Administration, the U.S. Department of Energy, the U. S. Department of Agriculture, and the National Institutes of Health.

Earth Systems Education in Context

Three presentations at the 1994 symposium highlighted the big picture of what an Earth Systems approach looks like and why it is valuable to students. The presentations are included here to represent three levels of Earth Systems Education implementation.

1. A Teacher's View.

Dr. Ed Shay was one of the early founders of the Earth Systems Education effort. A science teacher in grades 9-12 of the Worthington Alternative Program, he had been integrating sciences in his classes and using modern approaches and tools intuitively. In ESE, Shay was able to assemble the rationale for these approaches and have the integration of sciences legitimized by the scientists themselves. In his presentation, Shay addressed the importance of teachers in the process of curriculum change, and the need for teacher input to be valued as expert knowledge at all phases of reform.

2. The perspective of higher education.

Many of those who are attempting to innovate in science education at K-12 levels find their frustrations magnified by the types of preparation still being offered in institutions of higher education. If all the science a teacher has ever had was delivered through disciplinary courses using a lecture mode, the teacher has no role models for using interdisciplinary science and collaborative learning techniques. There is also little opportunity in certification programs to develop an interdisciplinary background with which to integrate K-12 courses.

Fortunately some scientists have seen the need for interdisciplinarity as well, and have secured federal assistance for integrating at least the geosciences in 22 institutions of higher education throughout the US. The Universities Space Research Consortium (USRA) supports the development of both introductory and senior level capstone courses, and Earth Systems Science courses in these key institutions. Participating institutions share speakers and ideas, as well as developing plans for continuation and expansion of the program after funding expires. Dr. Michael Kalb's presentation detailed these important contributions to Earth Systems efforts.

3. The GLOBE program

Global Learning and Observations to Benefit the Environment (GLOBE) grew out of Vice-President Al Gore's book, *Earth in the Balance*. The program involves data collection by students at all grade levels, according to standards outlined by scientists who agree to use the data in global monitoring and research. Funds and training are provided to the US participant schools (1700 in Year 1). Data are shared on-line through a central collection and processing unit in Boulder, Colorado. Other countries participate in the data collection as well, making this a truly global program. Countries registered to participate as of April 1995 are

Belgium	Croatia
Egypt	Finland
Israel	Kazakhstan
Moldova	Netherlands
Norway	Romania
Russia	Senegal.

The GLOBE program is funded by a consortium of federal agencies including NOAA, NASA, the Department of Education, and EPA. At the symposium, Dr. Barry Rock, science advisor for GLOBE in its first year, illustrated GLOBE processes through slides and commentary. A description of the program follows, and up-to-date information can be found at GLOBE's WorldWide Web site (http://www.globe. gov/).

Edwin L. Shay
Retired B.E.S.S. Teacher
Worthington City Schools, Ohio

ESE: A Teacher's View

Consider the need, and our failure, to communicate the following crucial idea:
"Science is the only self-correcting human institution but it is also a process that progresses only by showing itself to be wrong."

– Allan Sandage, astronomer
in *Puget Sound Computer User*
August, 1994

Factors Influencing the Development and Implementation of Earth Systems Science

A. Local factors that influenced the development of Biological and Earth Systems Science in Worthington OHIO

1) Observation: Sophomores who were 3/4 of the way through chemistry were getting interested in environmental issues. Having been "guided" past earth science in the rush to get to AP courses, they did not have the context in which they might approach the topics. Most felt it was either too late or too "uncool" to go back and take Earth science with the freshman.

2) Discussion: Talking with other science teachers who had led field studies programs to the Bahamas generated the idea that teenagers placed in an unfamiliar ecosystem were unable to see biotic-abiotic relationships necessary to operate the system.

3) Feedback: Polling former students led to their commentary which was basically, "you folks are nice people and probably mean well, but the amount of vocabulary and detail you had us memorize is gone. It was a waste of time and [what's worse] a real turn off about the sciences as a career."

4) Individual reflection: How educated a science teacher do you need to plod through a textbook, even one approaching 700 pages long? The honest questions were raised, "Is that all there is to science teaching? Will this minutiae really turn teenagers on to science? Is this detail really representative of what is going in science?"

5) A willingness to deal with the question, "what is it that we want every 17 year old to know–and why ?"

B. What's important, and possibly different, for you to be a successful Earth Systems facilitator ?

The following admittedly incomplete list is based on the assumption that if you are generally interested in becoming an Earth Systems "teacher," it must change the way you teach.

1) You cannot function alone, in part because you cannot know enough. You must interact with your colleagues. On a personal note, this was one of the most exciting outcomes of our move towards earth systems science – you need the people with whom you work.

2) If #1 is true, then a corollary would be that the students must also have the opportunity to work

together.

3) Earth Systems science may change the types of things you read, the connections you help kids make and the way you in corporate new materials for class.

4) You simply must get better at leading discussions. You must listen better to teenagers and it is important– even crucial–to develop better questioning skills.

5) a. You need to be able to encourage and then impact divergent points of view on science issues that are supported.

b. You can't preach the party line on environment or any other issue. You are entitled to your supported opinion but not at the expense of intimidating other learners in the room. There is also no surer way to turn some teenagers against something than for you to be forcefully in favor of it.

c. All this leads to the idea that you may occasionally have to be okay with a lack of closure. (Please note that closure is very different from debriefing which has proven to be absolutely necessary.)

> A social studies colleague has tried to show young people that "complex issues are complex because the real world is complex." Stop looking for black and white answers. If you can come to closure as a group on an issue like "the spotted owl vs the logger," you probably don't even understand the problem.

6) While your basic curriculum outline might undergo minor changes from year to year, the specific content will change as the significant issues in science change. Congratulations! You've just become a real learner for a lifetime.

7) If you understand that you cannot possibly "teach" everything about a topic, then content needs to consist of a common thread–materials all the students are exposed to, and a "personal time" for the individual and small group to search out specific interests. And remember, to guide and that you can help students learn how to form and seek out the answers to science questions. This will pay them dividends a long time after they've forgotten the 16 parts of a liverwort.

8) Right-brained activities and contributions must be learned in the science classroom.

9) Learn to delegate. You've got to take help where you can get it. Sometimes things will work, sometimes they won't. Don't get discouraged. Teaching is like fishing! You won't get a bite on every cast. One person I taught with summed up Earth Systems science with the greatest compliment I've ever heard for a program when he said, "Teaching BESS has changed the way I live."

Being involved in Earth Systems science is exhausting and exhilarating. It seems like you are "on" 18 hours a day. There is so much information available now that you simply must face the challenge of deciding what's the most valuable use of the days you have with teenagers. Think about how you do your job. Decide how best to be a brief part of their lives. Represent real science and real, living scientists. Represent the excitement and the fun and the challenges that got you to choose your profession.

The best representation of the "spirit" of earth systems science was written a number of years ago by nature writer Barry Lopez in CROSSING OPEN GROUND. Read the short story, "Children in the woods." It will give you all the teaching philosophy you'll ever need.

USRA/NASA COOPERATIVE UNIVERSITY-BASED PROGRAM IN EARTH SYSTEM SCIENCE EDUCATION "ESSE"

PROGRAM OVERVIEW

Dr. Michael Kalb

Earth Systems Education High School Sympopsium October 1994 Columbus, Ohio

The Cooperative University-based Program in Earth System Science Education

I. Background

In the mid 1980's concerns within the scientific community regarding man's ability to impact ecosystems on a world-wide scale were accelerated when the first hard evidence emerged to suggest that ozone depletion and global warming might be real threats. It was also recognized that understanding man's ability to both cause and adapt to large scale environmental change requires an integrated view of how the biosphere, the physical climate system, and humans interact mutually within a single Earth System. By the late 1980's "Earth System Science" emerged as a framework for addressing the geoscience dimensions of global change.

After extended discussions, NASA and university scientists concluded that for the interdisciplinary approach to Earth Science to be successful, mechanisms were desperately needed to stimulate scientific collaboration among scientists and departments within universities, among universities, and between university and government science communities. As a result of those discussions, USRA formulated a program concept aimed at creating a university-based cooperative effort in Earth science curriculum development, within a framework designed to overcome traditional barriers to interdisciplinary science education.

In 1991 the Universities Space Research Association and the National Aeronautics and Space Administration initiated the Cooperative University-based Program in Earth System Science Education (ESSE) that linked faculty from twenty-two U.S. universities with one another and with NASA scientists to accelerate the development of undergraduate curricula in Earth System Science. The outward objectives of the program were to foster the establishment of a national academic forum for Earth System Science for undergraduate education as a whole, and to expand the interdisciplinary interests and number of future scientists who elect to pursue Earth Science research professionally.

Twenty-two universities were competitively selected by NASA to participate in a five-year program based on proposals addressing these interdisciplinary needs, evidence of faculty interests, and institutional commitment to development of interdisciplinary Earth Science curricula. This effort is now entering its fourth year.

II. Description of the Current Program

Within the ESSE program, each university offers at least one survey course and a senior level course in which faculty present Earth Systems issues as a socially relevant, challenging, and important class of scientific problems. The objectives of the survey level course are to present an overview of Earth Sciences from a system perspective, introduce physical mechanisms and feedbacks involved in global change, and provide a scientific understanding of inter-relationships between the Earth's physical climate system and ecological systems. This course aims to instill among the general student population an appreciation of the social, economic and political implications of global change

The objective of the advanced senior-level course is to both provide a systems view of the Earth to undergraduate science majors and to motivate outstanding students in the sciences and mathematics to pursue graduate studies, and eventually professional careers, in interdisciplinary Earth Science and global change research. In these classes, senior-level students from different academic departments work as a team to implement conceptual and computer models of physical and chemical processes that link the physical and biological components of the Earth System in a problem-solving, project oriented environment. The senior course is taught by faculty members from at least two relevant academic departments, and focuses on scientific issues that draw upon the strengths of the institution.

As part of the broader program, universities participate in an exchange in which visiting faculty and scientists from other participating universities and from NASA bring to the class-room expertise and perspectives different from those at the host campus. The ESSE program facilitates these interactions by providing logistical and travel support directly to scientists from participating universities to visit other universities. These visitors are expected to present guest lectures in the undergraduate classes, present scientific seminars, and hold discussions with faculty, staff, students and administrators.

A principal faculty coordinator (PI) has primary responsibility for promoting, co-ordinating, and conducting the activity within his/her own university. The coordinator identifies faculty and staff for teaching and travel to other ESSE universities, hosts visiting ESSE faculty and NASA scientists, and works with a NASA sponsoring scientist to identify course projects relevant to NASA, and NASA resources and data that could be made available for classroom use.

The faculty coordinators from all the universities contribute collectively to the direction of the program through their participation in a steering committee that meets twice each year. Faculty come together at these meetings to discuss common problems and approaches to the development of course content, laboratory exercises, and the development of interdisciplinary Earth Science programs at their universities. This group is intended also to constitute a recognized forum for addressing larger problems in Earth System Science education, such as graduate level programs, and development and testing of texts and teaching materials.

Each principal faculty coordinator and university program is linked with a NASA affiliate scientist who contributes informally to the university's academic program, advises on curriculum and class projects relevant to NASA missions, and facilitates access to NASA data, technical material and other resources appropriate for use in the undergraduate courses. Each summer, the principal faculty coordinator and a teaching assistant have the opportunity to spend up to two weeks at a NASA center working with their NASA affiliate scientist to discuss scientific problems of importance to NASA, and to identify resources available for classroom use. The NASA affiliate is encouraged to spend several days each academic year as a guest lecturer at the sponsored university.

The overall success of the current program may be attributed to the "bottoms-up" approach. In this approach, faculty participants with genuine desire and modest NASA support have leveraged a four/five fold allocation of local university resources in the form of faculty salaries, classroom time, technology, etc. towards their Earth System Science courses. Furthermore the impact of the NASA support will be long-lived, in that the courses and interests in Earth System Science initiated in response to this program will continue for the remainder of the decade and into the next century.

ESSE attempts to fulfill real needs in providing for exchange among disciplines, universities and NASA at the working level. For the most part, university structures suppress efforts in education directed toward global change by virtue of the emphasis given to the competitive strengths of disciplines as opposed to that needed for collaborative interests *across* disciplines. Faculty who respond to the educational interests of global change often require support on the larger scene from peers engaged in like endeavors, not only in the form of personal reinforcement, but ultimately more importantly in the knowledge that they contribute to and gain access to a larger repository of knowledge in Earth System Science and global change. By virtue of discipline interests, few if any professional societies are positioned to meet this need.

III. Activity Summary and Status

In Academic year 1991-1992, the first seven ESSE universities reported course enrollments of 1316 at the survey level and 175 at the senior level. Thirteen universities received full stipend (25K) and travel support under the ESSE Program during the 1992-93 academic year. The travel funds, which support faculty exchange, travel to NASA centers, and attendance by participating faculty at steering meetings, were available to all twenty-two universities in the program. Total survey course enrollment in academic year 1992-1993 was 1,679 and senior course enrollment was 518. In the 1993-1994 academic year seven schools are offering the courses for the first time under ESSE. AY 93-94 enrollments were 2828 and 693 in the survey level and senior levels respectively. An attached table summarizes the universities, faculty and departments involved, course titles, and enrollments. During the next two years of the current program, the projected total enrollments in courses developed with support from the ESSE program will likely exceed 3,000 students at the survey level, and 1,000 students at the senior level.

Steering meetings were held in October 1991 and June 1992 near NASA Goddard, December 1992 at Stanford University, in June 1993 at NASA Langley in Hampton, VA, and in January and June 1994 at the University of Maryland. Program participants come together at these meetings to discuss common problems and approaches to the development of course content, laboratory exercises, and the development of interdisciplinary Earth Science programs at their universities. These meetings are regarded by many of the ESSE participants to be the most valuable part of the program.

In addition to the steering meetings, in July 1992 a three-day workshop on "Modeling in the Classroom" was held that involved training faculty and teaching assistants from all twenty-two ESSE universities on the use of the STELLA system modeling software. In January 1994, in conjunction with the ESSE Winter Meeting, a training workshop was held involving ESSE faculty and teaching assistants dealing with the classroom implementation of the "Geoscope Global Change Encyclopedia". The workshop was jointly sponsored by USRA, NASA and the Canadian Space Agency, which produced Geoscope for the International Space Year. "Geoscope" is a PC-based, CD-ROM driven interactive system that facilitates display and analysis of Earth Science data in tandem with instructional text, glossary and socio-economic data bases.

Although the course organization and teaching format varies widely from university to university, the survey courses are typically being taught by two faculty members. The senior courses are being taught by faculty from two or more departments and/or disciplines as intended under this program, and include guest lecturers. The departments and academic programs involved in these courses cover a wide range of discipline interests, including: Agricultural and Irrigation Engineering, Atmospheric and Oceanic Sciences, Biological Sciences, Chemical and

Biochemical Engineering, Civil and Environmental Engineering, Economics, Earth and Space Science, Earth and Planetary Sciences, Ecology and Evolutionary Biology, Forest Resources, Geography, Geology and Geophysics, Geosciences, Marine Science, Meteorology, Physiology and Biophysics, Physics, Plant, Soils, and Biometeorology, Space Physics and Astronomy, Soil and Water Science, and Tree-Ring Research.

In most instances, materials developed for a class at each ESSE university are computer oriented, and are suitable for electronic delivery. Currently the development and delivery of these materials is within the participating departments, schools and/or colleges. At the moment no uniform mechanism exists for ready exchange of the material beyond the local institution. At the ESSE Workshop in January, 1994, network access to tools and curriculum materials were designated a priority need. Based on the recommendations of the ESSE steering committee, a World Wide Web (W3) server is being developed to provide for efficient collaborative development and access of publishable quality educational modules among the ESSE participants and also for access by the Internet community at large. This server will provide for the development of an Internet-based USRA/ESSE server with a repository of Earth Science educational resources that will both serve and reach beyond the ESSE universities.

It is anticipated that a new call for participation will be issued by USRA and NASA during the first quarter of 1995 year to include a new group of universities in a continuation of the ESSE effort. Questions regarding the program should be directed to:

Dr. Donald R. Johnson (608) 262-2538
Space Science and Engineering Center
1225 W. Dayton Street
Madison, Wisconsin 53706

or

Dr. Michael W. Kalb (301) 805-8396
Universities Space Research Association
7501 Forbes Blvd., Suite 206
Seabrook, MD 20706

STELLA

STELLA is a commercial software package that allows a user to graphically build dynamic models that normally would be represented mathematically by a set of ordinary differential equations. The advantage of STELLA is that the user deals only with logical concepts in constructing a model. Without the need to solve or understand differential equations, STELLA is accessible to students of the social as well as the math-based sciences. Originally developed as a tool for economists, STELLA is used for research among the ecosystem modeling community. It has been used successfully at the high-school level.

A model is built graphically on the computer screen by arranging symbols representing system parameters, sources, sinks, input and output, and then connecting them with of pipes and valves to establish a framework describing qualitatively the interactions and feedbacks between the parts. The model is completed by providing additional information that describes dependencies between components. The software supports animated graphical display of model output, scenario testing, and detailed examination of the inter-dependencies between model variables.

Most ESSE universities have implemented STELLA for demonstrating systems concepts, and examining interactions within the Earth System. It is being used widely in the ESSE classroom for demonstration and for laboratory exercises.

A new version of STELLA has been released that will allow pre-prepared model files to be downloaded, and a model executed and displayed under user changeable parameter settings, without the need to have the full version STELLA software. Such STELLA run-time models will be made available to the community through the USRA ESSE server.

GEOSCOPE

One of the unique educational resources available to the ESSE universities is GEOSCOPE. Developed by the Canadian Space Agency and the Canada Centre for Remote Sensing, GEOSCOPE is an electronic encyclopedia of global and regional Earth Science data sets, and world resource information, with capabilities for authoring and multi-media presentation. NASA, NOAA and other space agencies contributed a wealth of data to populate the GEOSCOPE database as part of the International Space Year effort in 1992.

GEOSCOPE offers tools for manipulation and comparison of regional and global data sets that have been co-registered on a common global grid. For example, sea surface temperature, phytoplankton concentration and ocean bathymetry can be analyzed and relationships established that enable understanding of processes affecting ocean productivity. Analyses that address a topic are readily incorporated into electronic "scenarios" that include hyper-referenced text descriptions, imagery and animation. ESSE participants are already utilizing GEOSCOPE to generate a series of Earth System scenarios for use in the laboratory and classroom. A follow-on product is GEOSCOPE NETWORK which will also incorporate Internet access to the W3 archives. USRA, under the ESSE program plans to operate a GEOSCOPE NETWORK server within the year.

GEOSCOPE is also the basis for the Canadian Electronic Atlas of Agenda 21 (ELADA 21) which aims to create a user friendly electronic interface to the Agenda 21 United Nations documents.

Earth System Science Education Program Participants

University	Principal Faculty	Participating Departments	Survey Course	Enrolled 92/93	Enrolled 93/94	Senior Course	Enrolled 92/93	Enrolled 93/94
University of Alabama - Huntsville	Richard McNider Stan Kidder	Atmospheric Scien	Earth System Science		26	Earth Sysem Modeling		13
University of Alaska - Fairbanks	Joshua Schimel	Biology Political Science Marine Science Physics	Humans in the Earth System	3	10	The Earth as a System	13	13
UYniversity of Arizona	Lisa Graumlich	Tree Ring Laborato Soil & Water Sciences	Intro. to Global Change	52	60	Global Change	74	95
University of California - Los Angele	Richard Turco	Atmos. Science	The Earth: How it Works		50	Environmental Chem Lab		15
University of California - Santa Barb	Raymond Smith Catherine Gautier	Geography Biology	The Earth from Space	29		Earth System Science	10	
University of Florida	David Hodell	Geology Aquatic Science	The Earth as a System		97	Global Biogeochemical Cycles Modeling the New Earth System		14 12
University of Iowa	Jerald Schnoor Frank Weirich	Geography Chem & Biochem Eng Civil & Env Eng Phys. & Biophysics	Intro. to Earth System Science	200	200	Atmos. Chemistry and Physics	35	35
Johns Hopkins University	George Fisher	Earth & Plan Scien	Environmental Earth Systems	47	47	Modeling Earth Systems	5	5
University of Minnesota	Kerry Kelts Paul Weiblen	Limonological Res	Our Changing Planet		125	Geosphere/Biosphere History		15
University of New Hampshire	Robert Harriss	Earth Sciences	Global Environmental Change	132	102	Energy for a Sustainable Future Global Hydrology and Water Resources	15	12
New York University	Michael Rampino	Applied Sciences	Earth System Science		70	Gaia: The Earth as a System		35
Northwestern University	Abraham Lerman	Geological Science	Earth: A Changing Planet		270	Biogeochemistry of the Earth System		9
Ohio State University	Ellen M. Thompso	Geography Geological Science Civil Engineering	Geology and the Environment Global Environmental Change	70 8	70	Integrated Earth Systems	15	15
Penn State University	Eric Barron Jon Nese	Geography Geosciences Meteorology	Earth as a System	780	780	Numerous ES Courses	280	280
Princeton University	Henry Horn Jorge Sarmiento	Civil Engineering Geological Science Ecology and Evol. Bio	Environmental Studies Perspec	90	90	Intro to Physical Oceanography Biogeochemistry of the Earth System	20	25
Purdue University	Ernest Agee John Snow	Earth and Atmos. S Forestry & Nat. Res	Survey of Earth System Science		20	Modeling the Earth System		12
Rice University	Arthur Few	Space Physics & A Ecology & Evol Bio	Atmosphere, Weather and Clim	117	117	Earth System Dynamics	13	13
Stanford University	W. G. Ernst J. Roughgarden Susan Alexander	Geology Biological Sciences Earth Systems Prog	Intro. to Earth Systems	61	114	Senior Seminar in Earth Systems	10	20
Rutgers University	James Miller	Meteorology	Perspectives in Agriculture and Env.		500	Seminar ESSE Colloquium		12
Utah State University	Jim Evans Robert Ford	Geology Plants, Soil & Sci Geography Watershed Science	Intro. to Earth System Science	25	15	Climate - Hydrologic Interactions	6	12
Washington University	Ray Arvidson Bruce Fegley	Earth and Plan Sci Biochem/Earth Sci	Biochemistry	21	21	Hydrology	13	13
University of Wisconsin	Francis Bretherton	Atmos & Ocean Sc	Global Change - Atmospheric Is	44	44	Earth System Modeling	9	16
Total				1679	2828		518	693

THE GLOBE PROGRAM

Global Learning and Observations to Benefit the Environment (GLOBE) is an international science and education prog:am. It creates a partnership between students, teachers, and the scientific research community that actively involves the students in data collection and observation. GLOBE is a long-term program with a clear central concept: Students from the ages of approximately five through eighteen years in schools throughout the world will conduct a continuing program of scientifically meaningful environmental measurements. The schools will be linked by modern telecommunications, so the students can transmit their data, receive data from other GLOBE schools, acquire information from a variety of sources, and collaborate with scientists and other GLOBE students and communities worldwide in using these data for education and research.

The measurements taken by the GLOBE students will serve two important purposes. One is scientific. Participating scientists will use these data in their research programs to improve our understanding of the global environment. The other is educational. Students will not only learn how to carry out a scientifically rigorous program of Earth observations, but will also use their own measurements, together with data from other GLOBE schools, as a key part of their study of environmental science. Through contact with and mentoring by scientists, the students will have feedback as to the value of their data sets. As a result, they will become full participants in an international program of global scale research.

GLOBE will also provide extensive educational materials to enrich the learning experience of participating students. These materials include a wide variety of classroom and field activities to help students place their measurements in a broader context and relate their own local observations to global environmental issues.

GLOBE is a hands-on school-based program that will:

- *Enhance the environmental awareness of individuals throughout the world;*
- *Enable students to make environmental observations that will contribute to improving our understanding of planet Earth;*
- *Give students the opportunity to work with respected scientists, collaborating through a worldwide network;*
- *Involve students, teachers, and scientists in sharing information about the global environment;*

Contact information
Mail address:
The GLOBE Program
744 Jackson Place
Washington, DC 20503

telephone 1-202-395-7600
fax: 1-202-395-7611

Inquires by Internet:
info@globe.gov
[a*human* will respond]

Express/courier address:
The GLOBE Program
The White House New
Executive Office Bldg
725 17th Street G-1
Washington, DC 20006

The GLOBE Program

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The GLOBE Program is a public-private partnership. It will build cooperative efforts, worldwide, with private sector organizations, industries, and businesses that support environmental science and education. Finally, GLOBE will grow as a result of the increasing commitment of nations and their governments throughout the world.

Research Missions identified within GLOBE are:

Land Cover
This exercise consists of two separate activities: one based on an analysis of a satellite image of the school, with a focus on selecting the study sites to be used in the secondary activity, which will result in a detailed assessment of the vegetation occurring in the study site. This will give students an opportunity to contribute to our understanding of land cover types in their area and its effect on greenhouse gas levels in the atmosphere.

Species Identification
An essential part of assessing the diversity of species characterizing a site is learning to know how to recognize species for your school area. To do this, schools will be directed to use an appropriate dichotomous key, developed for use in their own country. Comparing species composition for adjacent school sites within a region and between regions will provide insight into the biodiversity of various regions.

Biometry
By knowing the size and numbers of individual plants, the biomass for a site can be calculated. Biomass is important as it has a positive relationship to the amount of CO_2 removed from the atmosphere. For this activity, students will use simple tools to measure the height, diameter and percentages of ground cover.

Phenology
Simple monitoring and recording obvious changes in the dominant species within a study site by students, significantly contributes to effort by scientists to monitor phenologic variables which contribute to scientists' ability to monitor global change.

Global Positioning System
To enable scientists to understand why changes occur in the Earth's environment it is important to record when and where measurements are made. This information is determined for each school and recorded within a satellite image.

Hydrologic Factors
Obtaining a better understanding of hydrologic processes is vital for improving our model of global circulation and climate. Observations of soil moisture, water temperature, water pH, air temperature, precipitation, and cloud cover can easily be collected by students in various regions.

Issues in High School Science Curriculum Restructure

"Discipline bigotry."

It is difficult to break the hold of the traditional science disciplines on the curriculum, particularly at the high school level. In the typical US high school, students take biology, chemistry and physics, usually in that order. Earth sciences are offered only in about 3% of high schools, and where it is available it is frequently used as the science course for the less able students (Mayer et al,1992). In most cases, Earth science is not even mentioned among the sciences or science courses (Carpenter, 1994). As integration of the science curriculum is proposed by national reform efforts, a combination of biology and earth sciences is a possibility, and this will at least offer students a view of the importance of the abiotic environment in creation and maintenance of habitats (Fortner, 1989). Less common is total integration of the type that would allow consideration of the chemistry and physical processes of Earth and life.

What IS important to know?

"The present curriculum is overstuffed and undernourished," proclaimed Science for All Americans (AAAS 1989). The first step in Project 2061 was to establish among the sciences the body of knowledge that every 17-year-old (high school graduate) should possess. Unfortunately this was approached by discipline, and no separate list was produced for the Earth sciences. As a remedy, Mayer and Armstrong (1990) published a consensus paper on "What every 17-year-old should know about planet Earth." This document served as guidance for some of the Earth Systems education effort and was eventually synthesized into the initial Framework of Understandings for Earth Systems Education.

In general, the restructured curriculum proposed by all reform efforts is one in which "less is more," in other words, fewer topics are necessary in the curriculum, and the selected ones can therefore be learned in greater depth. To be sure, that makes the selection of content extremely important, and it requires turning loose of some favorite topics as requirements for all students.

Equivalent achievement (to past standardized scores).

If the high school curriculum is to be changed, the positive impacts must be reflected in recognizable forms. For most people this means standardized test scores. Unfortunately, the existing tests measure traditional vocabulary-laden science and linear processing of the kind that reflects traditional teaching in the disciplines. If we teach to the test, and choose textbooks for the test content, we will not be restructuring science. To espouse a systems approach to teaching science would mean that testing modes would need to change as well. While some attempts are being made to change tests, it is likely that those alterations may be long in coming and even longer in achieving acceptance.

It is imperative for restructured high schools to make a case with college and universities for the acceptability of their new courses for college entrance. This has been successfully done with no difficulties in cases such as the Biological and Earth Systems Science (BESS) course in Worthington, OH. Those colleges contacted, including Ivy League schools and other major universities, indicated that a school's identification of a course as being a "laboratory science" was sufficient for its acceptance, and that these institutions were more interested in the number of science courses students took compared to the number available (BESS 1994).

Time and Resources

According to Project 2061, "To change this [overstuffed and undernourished curriculum] will take determination, resources, and TIME." It is widely acknowledged that allowing teachers time for reflection and development is key to accomplishing curricular improvements (NCSESA, 1994). When the BESS program was in its development phases, teachers were given common planning periods and relief from one teaching period per day. For the second year's development effort, which was going on while BESS I was in its pilot year, two teachers were released for an entire semester to work on the course. To do this required a grant to support additional instructional positions to replace the released teachers. In Earth Systems Education workshops, teachers were provided with large blocks of time for working in grade level or regional groups, so that their growth would include professional encounters in sharing insights, resources, and concerns.

As for resources, there is a lack of integrated science material at the high school level. Teachers wishing to integrate their teaching do so with self-constructed materials, team teaching, and a few existing curriculum materials such as those in global change education (ACES from The Earth Systems Education Program, GEMS from the Lawrence Hall of Science, etc.), other environmental topics, and STS materials. If a technological component is desired, it must either use existing hardware and employ traditional software such as generic spreadsheets, or be very low cost additions to hardware or software. Otherwise it must be deferred until support for higher levels of computers, phone line access for networking, and funds for software are secured.

Social Issues (in class)

The best implementation of Earth Systems Education is done through student collaborative investigations, in which students must seek the information needed for consideration of solutions to a problem, and apply information from a variety of sciences and sources. Literature supports the use of heterogeneous groupings for collaboration of this sort, because the diversity of skills, backgrounds and interests in mixed groups simulates that to be encountered in the workplace (SCANS), and the ideas of such groups tend to be more diverse than those who have all been achievers at the same academic level. (Brown and Campione, 1994)

In most high schools, however, students are grouped by ability. Students who achieve well in traditional (individual) learning modes express frustration at dealing with group process, and the parents of these students clamor for enriched courses that segregate their learners from those with different ability levels. While these problems usually arise from only a few parents and students, they are a vocal minority that will require satisfaction. Integration of the high school science classroom will need to meet this challenge through constant communication with parents and frequent reinforcement of students for their group roles.

Social Issues (in the content)

Many of the attempts to integrate the science curriculum have dealt with understanding of complex science/social issues, such as AIDS, global warming, extinction rates of modern species, use of Geographic Information Systems, and the like. As these have a significant social element in addition to the science, they stand out as targets for those who would maintain traditional science programs. As Dr. Paul DeHart Hurd has said, "Everyone wants progress, but nobody wants to change!" The movement toward science curriculum restructure has been fueled at least as much by the need for curriculum relevance as it has by comparison of US test scores with those of other countries. students need to see science as relevant to their lives, as meaningful in decisions they themselves will make. Thus inclusion of social issues in their science context is an important part of restructure. (NCSESA, 1994)

How do people learn/teach?

As we look at the changes now being implemented in curriculum restructure, it is critical that we look also at the new generations of teachers who will enter these classrooms. If they continue to teach as they were taught, the restructured curriculum will fail. Especially in Earth Systems Education, there is a need for flexibility in the classroom structure, to accommodate group process, allow time and resources for searching for information relevant to issues, and plans for rewarding accurate and meaningful expressions of science learning. If teachers enter the classroom expecting to dispense an array of facts, they will not be doing ESE. If they evaluate group process with multiple choice tests, they are not assessing all that has been learned. There is a need, therefore, expressed frequently by symposium participants, to reconstruct teacher education as well as K-12 education.

Participant Presentations

The following pages are reports of how various individuals, schools, districts and states have attempted to make their science a study of Earth. Their infusion of Earth Systems concepts ranges from development of single activities and case studies, to interdisciplinary team activities, complete course overhaul, new course development, and use of ESE in state curriculum reform. Contact information for teacher/presenters is given, and complete addresses are in the Participant List in the Appendix.

Courses	Presenter(s)
Biological and Earth Systems Science (BESS) Worthington, OH	Mark Maley, Ron Pilatowski, Brian Luthy
Earth Systems Regents Course Millbrook HS, NY	Jerry Sherman
Advance Earth Systems Science and Technology Marple Newtown HS, Newtown Square, PA	Al Capotosto
NASA Classroom of the Future Wheeling Jesuit College, Wheeling, WV	Robert J. Myers
Earth Systems Education Roy Ketcham HS, Dutchess County, NY	David Kibler
Vision – Columbus Urban Systemic Initiative Columbus Schools, OH	Gloria Letts
Integrated Science Omaha North HS, Omaha, NB	Kelly Gatewood
Field Biology Salem, OR	Jon Yoder

Units and Lessons

Case Studies in Environmental Science Concord Academy, Concord, NH	William S. (Tad) Lawrence
Interdisciplinary Study of the Cache La Poudre River University HS, Greeley, CO	Ray Tschillard, Arvon Engel, Dan Warner, Dan Wagner
Integrating ESE into the High School Curriculum State Systemic Initiative, Pierre, SD	Joan Dutt
What affects ozone levels? Gateway Regional HS, Huntington, MA	Jeffrey A. Samson

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Biological and Earth Systems Science

-BESS-

WORTHINGTON CITY SCHOOLS
752 HIGH STREET
WORTHINGTON, OHIO 43085
(614-431-6500)

THE GENESIS OF BIOLOGICAL & EARTH SYSTEMS SCIENCE

We are being presented with almost daily reminders of the results of abuse and neglect of our Earth system 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. In general, the public has been ambivalent toward science and has a poor understanding of what science is telling us about the Earth. 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, Earth.

The viewpoints expressed in the statement above have led to some of the most massive research ever undertaken in curriculum development. Many national projects initiated during the 1980's are only now beginning to affect our curriculum. Science education has seen the highest monetary expenditure of any area of curriculum reform. Two studies which have had a direct impact upon the development of our Biological & Earth Systems curriculum include "Project 2061" of the American Association for the Advancement of Science (AAAS), and the "Scope, Sequence and Coordination" (SS & C) effort of the National Science Teacher's Association (NSTA). Therefore, several groups of science educators came together to revise science curriculum in a manner consistent with an Earth systems view. First, the National Science Foundation gathered a group of leading educators and geoscientists who, in 1985, constructed a K-12 syllabus including earth systems content throughout the school curriculum. Second, a two-year series of conferences including educators and scientists from all disciplines met in 1988 to identify the goals and concepts about the Planet Earth that "every 17-year old should know." A member of the Worthington Schools science staff attended this conference in response to studies already underway within the Worthington Schools, leading to the beginning of the BESS curriculum model.

The concepts and goals which were produced as a result of the work of all four of the above groups were combined and submitted to a national group of science educators meeting at The Ohio State University in May 1990. This group has become known as the "Program for Leadership in Earth Systems Education" or PLESE. The results of this meeting in May 1990 are the broad concepts we undertake in Biological & Earth Systems Science. The syllabus and teaching materials for this class revolve around a study of the Earth and the subsystems which make it a whole.

The goal of science education during the 1980's is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual network, and process skills that enable the individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations.
–*from NSTA's position paper on Science, Technology, and Society*

BESS LEARNING STRATEGIES

Based upon current research in science education, science should be less teacher-centered with an emphasis on the student and on the process of learning science. In designing the BESS program, these considerations were taken into account. BESS places an emphasis on:

- Problem-Based Learning
- Use of current technology
- Information acquisition
- Analysis, evaluation, interpretation and application of information
- Group learning

A variety of strategies are employed to facilitate the learning process. These strategies include laboratory work, projects, peer teaching, field experiences, lecture, and discussion.

Assessment techniques used in BESS are designed to measure a student's understanding of material and a student's ability to analyze, evaluate, and apply information. Forms of such assessment have included student designed and constructed newspapers, videotaped programs, computer programs, simulation aids, reports and projects which emphasize science as a process rather than just a product. More traditional forms of assessment, such as tests and quizzes are also part of student evaluation.

BESS 1 FRAMEWORK

A. EARTH'S NATURAL SYSTEMS

A1 What is a system?
A2 Why is diversity important in a system?
A3 How and why do scientists classify parts of systems?
A4 How do Earth's natural systems change?
A5 What are some issues or concerns regarding Earth's natural systems?
A6 What tools and processes are used to study natural systems?

B. REMOTELY SENSED INFORMATION

B1 How are maps, aerial photos and satellite images used?
B2 How do comparisons of data/information over time show change?
B3 How do ground observations provide clues for the interpretation of aerial photos & satellite images?
B4 How is remote sensing used in astronomy and medical sciences?
B5 What are some issues or concerns regarding change and remote sensing?

C. WEATHER SYSTEMS

C1 How is remote sensing used to study weather systems?
C2 What is the source of energy in our atmosphere?
C3 What causes weather to change?
C4 What are the interactions between large bodies of water, land and atmosphere that influence weather?
C5 How can changes in the weather be monitored and predicted?
C6 How does weather affect you, and how does it affect other organisms?
C7 What causes violent weather such as blizzards, tornadoes, thunderstorms and hurricanes, and how can you protect yourself from these?
C8 What are some issues or concerns regarding weather systems?

D. EARTH'S NATURAL RESOURCES

D1 What are Earth's major natural resources and how do we use them?
D2 What are our responsibilities toward the use of natural resources?
D3 Which natural resources are renewable or nonrenewable and how can or should they be managed for sustainability?
D4 What are some of the positive and negative impacts of acquiring and utilizing natural resources?
D5 What are some of the positive and negative impacts of acquiring and utilizing natural resources?
D6 What are some organizations involved with environmental stewardship?
D7 What are some issues or concerns regarding Earth's wastes, pollutants and natural resources?

E. ECOSYSTEMS

E1 What remote sensing techniques are used to study ecosystems?
E2 How do landforms and soils develop?
E3 How does energy flow within an ecosystem?
E4 What are some interrelationships in an ecosystem?
E5 What are some issues or concerns regarding ecosystems?
E6 How are ecosystem relationships altered and what are some of the results of these changes?
E7 What are the factors that make terrestrial and aquatic biomes in the world unique?
E8 What effects do biomes have on global environments?

F. CULMINATING ACTIVITY

Students will be involved in a culminating activity which will explore and integrate many of the concepts and ideas developed during the first year of BESS.

BESS 1

CONCEPTS AND CONTENT

Unit A • EARTH'S NATURAL SYSTEMS

- •EXAMPLES OF SYSTEMS
- •BIODIVERSITY
- •BIOTIC/ABIOTIC FACTORS
- •EXAMPLES OF CHANGE IN SYSTEMS
- •SOLAR SYSTEM
- •CAUSE & EFFECT INTERRELATIONSHIPS
- •EARTH'S SUBSYSTEMS
- •BIOLOGICAL CLASSIFICATION
- •DICHOTIMOUS KEY
- •POPULATION DYNAMICS
- •REMOTE SENSING DEVICES
- •INTERRELATIONSHIPS

Unit B • REMOTELY SENSED INFORMATION

- •MAP SCALE
- •LATITUDE/LONGITUDE
- •USES OF REMOTE SENSING
- •PRACTICAL USES OF REMOTE SENSING (MEDICAL, ASTRONOMICAL, ENVIRONMENTAL)
- •TOPOGRAPHY
- •REMOTE SENSING DEVICES
- •INDICATORS OF CHANGE

Unit C • WEATHER SYSTEMS

- •SEASONS
- •EL NINO
- •WARM AND COLD FRONTS
- •JET STREAMS
- •LAND/WATER INTERACTIONS
- •COLLECTING WEATHER DATA
- •EMERGENCY READINESS
- •CONVECTION CELLS
- •CLIMATES
- •STORMS
- •WATER CYCLE
- •FORECASTING

Unit D • EARTH'S NATURAL RESOURCES

- •FORMATION OF RESOURCES
- •RENEWABLE VS. NON-RENEWABLE
- •STEWARDSHIP ORGANIZATIONS
- •HUMAN INFLUENCED GLOBAL CLIMATE CHANGE
- •HABITAT DESTRUCTION
- •ALTERNATIVE RESOURCES
- •REDUCE/REUSE/RECYCLE

Unit E • ECOSYSTEMS

- •INTRODUCTION TO NATURAL SELECTION
- •FOOD CHAINS/WEBS
- •BIOGEOCHEMICAL CYCLES
- •BIOMES/ECOSYSTEMS
- •COMMUNITY RELATIONSHIPS
- •PREDATOR-PREY RELATIONSHIPS
- •ADAPTATIONS (STURCTURAL, MORPHOLOGIAL, BEHAVIORAL)
- •GLACIATION
- •ENERGY/BIOMASS PYRAMIDS
- •TROPHIC LEVELS
- •NICHE
- •SOIL DEVELOPMENT
- •USES OF CHEMICALS

BESS 1

PROBLEMS AND ISSUES

Unit A • EARTH'S NATURAL SYSTEMS

- •WHALING
- •DEFORESTATION
- •EXTINCTION
- •HUNTING/FISHING/POACHING
- •ENVIRONMENTAL ETHICS
- •STEWARDSHIP
- •MARINE MAMMALS
- •ENDANGERED SPECIES
- •ZERO POPULATION GROWTH
- •HUMAN POPULATION GROWTH
- •ZOOS/PRESERVES

Unit B • REMOTELY SENSED INFORMATION

- •LAND USE/URBANIZATION
- •USES OF SATELLITE DATA (I.E. DEFORESTATION, OZONE DEPLETION, STORMS AND WEATHER, POPULATION GROWTH)
- •DOCUMENTATION OF CHANGE
- •FAMILIAR PLACES

Unit C • WEATHER SYSTEMS

- •WEATHER TECHNOLOGY
- •EMERGENCY READINESS
- •DROUGHTS
- •PLANNING FOR WEATHER CHANGES
- •GLOBAL CLIMATE CHANGE
- •ARTIFICIAL WEATHER CONTROL (I.E. CLOUD SEEDING)

Unit D • EARTH'S NATURAL RESOURCES

- •AIR QUALITY/POLLUTION
- •LAND ALLOCATION
- •FOSSIL FUEL DEPLETION
- •JOBS VS. ENVIRONMENT
- •NATURAL RESOURCE DEPLETION
- •GROUND WATER CONTAMINATION
- •SYNTHETIC REPLACEMENTS
- •REDUCE/REUSE/RECYCLE

Unit E • ECOSYSTEMS

- •PESTICIDES
- •WETLANDS DESTRUCTION
- •RAINFOREST DESTRUCTION
- •SOIL QUALITY
- •ANTARCTICA
- •ACID RAIN
- •ASBESTOS
- •WILDLIFE PRESERVES
- •OIL SPILLS
- •DEFORESTATION
- •DESERTIFICATION
- •FOOD ADDITIVES/ALTERATIONS
- •MAN-MADE CHEMICALS
- •NATURALLY OCCURRING CHEMICALS

G. REVISITING SYSTEMS

H. ORGANISMS AS SYSTEMS

H1 What technologies are used to study individuals?
H2 What is the internal structural organization of organisms?
H3 How do the internal subsystems of an organism function and respond to changes?
H4 What are the main biochemical processes that sustain organisms?
H5 How do the structures and biochemical processes of organisms function interconnectedly to achieve essential matter and energy exchanges?
H6 What are some factors that may change the normal functions of an organism's subsystems?
H7 What are some issues or concerns regarding the well-being of individual organisms?

I. THE EARTH AS A SERIES OF INTERACTING SYSTEMS

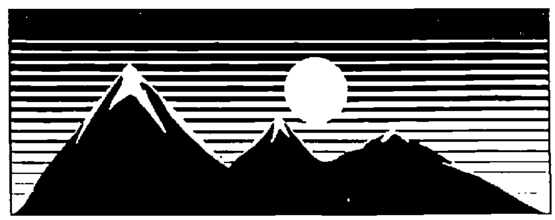
I1 How can changes in Earth's subsystems be monitored and prodicted?
I2 What are the causes and effects of crustal evolution and other major changes in Earth's subsystems?
I3 How does matter move through biogeochemical cycles involving different subsystems?
I4 What can fossils and other Earth archives tell us about the nature of and the rate of changes and interaction in Earth's subsystems?
I5 How and why are humans altering Earth's subsystems?
I6 What are some issues or concerns raised from these alterations?
I7 What should we do to minimize our negative impacts on changes in Earth's subsystems?

J. ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

J1 How do the major natural processes that may result in changes in species work?
J2 What changes in genetic diversity may result from these processes?
J3 What evidence is there for organic evolution?
J4 How are genetic information molecules replicated, transmitted, expressed, and altered?
J5 What are the mechanisms and principles of genetics/heredity?
J6 How and why are humans altering natural genetic and/or reproductive processes?
J7 What are some potential implications and impacts of these alterations?
J8 What are some issues or concerns raised by these alterations?

K. CULMINATING ACTIVITY

Students will be involved in a culminating activity which will explore and integrate many of the concepts and ideas developed during the second year of BESS.



BESS 2
CONCEPTS AND CONTENT

Unit G: REVISITING SYSTEMS

- CHAOS THEORY
- EARTH'S SUBSYSTEMS REVIEW

Unit H: ORGANISMS AS SYSTEMS

- ATOMIC STRUCTURE
- CELL STRUCTURE AND FUNCTION
- PLANT ORGAN SYSTEMS
- ANIMAL ORGAN SYSTEMS
- ENERGY REQUIREMENTS OF ORGANISMS
  (e.g. ENZYMES, CELLULAR RESPIRATION & PHOTOSYNTHESIS)

Unit I: THE EARTH AS A SERIES OF INTERACTING SYSTEMS

- MINERALS
- ROCK CYCLE
- WEATHERING AND EROSION
- OCEANOGRAPHY
- ROCK STRATA
- FOSSILS
- PLATE TECTONICS
- EARTHQUAKES AND VOLCANOES
- CONTINENTAL DRIFT

Unit J: ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

- GENETICS/HEREDITY
- MITOSIS
- MEIOSIS
- DNA REPLICATION
- PROTEIN SYNTHESIS
- GEOLOGIC TIME SCALE
- EVIDENCE FOR EVOLUTION
  (e.g. FOSSIL RECORD, BIOCHEMICAL, AND GEOGRAPHIC)
- MECHANISMS OF EVOLUTION
  (e.g. MUTATION, RECOMBINATION, & NATURAL SELECTION)
- NON-HUMAN INFLUENCED GLOBAL CLIMATE CHANGE

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BESS 6

BESS 2
PROBLEMS AND ISSUES

Unit G: REVISITING SYSTEMS

- THE STATE OF THE WORLD TODAY
- CHAOS THEORY
- WHAT'S NEW IN THE WORLD/INSTABILITIES

Unit H: ORGANISMS AS SYSTEMS

- TOXIC SUBSTANCES
- CHEMICAL DEFICIENCIES
- CARCINOGENS
- PARASITES
- BACTERIAL/FUNGAL/VIRAL AGENTS
- pH/TEMPERATURE VARIATIONS
- ANIMAL RESEARCH/WELFARE
- EUTHANASIA
- ORGAN TRANSPLANTATION

Unit I: THE EARTH AS A SERIES OF INTERACTING SYSTEMS

- WASTE DISPOSAL
- MINING
- OCEAN DUMPING
- SHORE EROSION
- SEA LEVEL CHANGES
- SHORE MODIFICATIONS
- STREAM CHANNELIZATION

Unit J: ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

- MUTAGENIC AGENTS (SUNTANNING)
- GENE THERAPY
- GENETIC COUNSELING
- ARTIFICIAL SELECTION
- REPRODUCTION TECHNOLOGIES
- MORAL/ETHICAL IMPLICATIONS
- GENETIC ENGINEERING AND BIOTECHNOLOGY
- CLONING, FERTILITY ENHANCEMENT, ARTIFICIAL INSEMINATION, IN VITRO, SURROGACY, ETC

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BESS DESIRED LEARNER OUTCOMES

- A holistic understanding of planet Earth
- Aesthetic appreciation of nature
- Understanding individual organisms, each one's place in a system, and its part in environmental processes.
- Awareness of human activities' impact on the planet Earth
- Demonstrate wise use of Earth's limited resources
- Use of current technologies as tools to access and process information
- Define problems and issues, and use skills for analyzing issues and solving problems
- Demonstrate individual and collaborative scientific endeavors
- Demonstrate effective communication skills within the context of science
- Understand the basic concepts and principles of science and apply them to solve problems, make decisions and understand the world
- Demonstrate awareness of science related skills and careers

BESS 7

UNIT A: EARTH'S NATURAL SYSTEMS

Potential Activites:
- Pond and river studies
- Classification methods
- The Solar System
- The scientific method
- Microscope and classifications labs
- Student developed computer programs
- Nature walks
- Access on-line databases
- Systems science
- Population studies

UNIT B: REMOTELY SENSED INFORMATION

Potential Activities:
- Reading topographic maps
- Use of technology in the medical field
- Types of equipment used to gather information about the universe
- Use aerial photography to investigate our local environment
- Investigate what we can learn and use from satellite photos
- Use CD-ROM technology to investigate remote sensing techniques
- Satellite images of Earth
- Map skills
- Changes in Worthington

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UNIT C: Weather systems

Potential Activities:

- Investigating the weather page of the newspaper
- Computer simulation games to investigate pollution associated with cities
- Student-made newspaper or weather television show
- Investigate the depletion of the ozone layer and prevention of this
- Investigate global warming—causes and effects
- Labs on the amount of carbon dioxide stored in certain types of rocks
- Air temperature and pressure labs
- Causes of wind and weather patterns

UNIT D: Earth's Natural Resources

Potential Activities

- Energy resources
- Agricultural resources
- Building resources
- Recreational resources
- Food resources
- Ore extraction lab
- Ohio's coal industry
- Methods used to obtain natural resources and associated problems

UNIT B: Ecosystems

WHAT HAS THE USE OF PESTICIDES DONE TO OUR WILDLIFE?

Potential Activities:

- Become an expert regarding a specific biome, and create a biome booth
- Investigate ways that we have altered or could alter our biome
- Food webs and energy pyramids
- The legacy of glaciers in Ohio
- Ecological relationships
- Soil studies
- Trouble with water
- Adaptation activities
- Groundwater
- Soil types
- Water issues
- Trophism labs
- Microbiology labs
- Permeability and Porosity lab

UNIT E: Culminating Activity

Students will be involved in a culminating activity which will explore and integrate many of the concepts and ideas developed during the first year of BESS.

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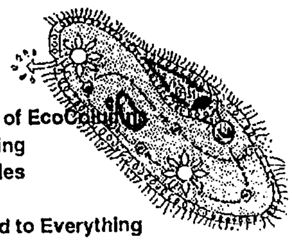
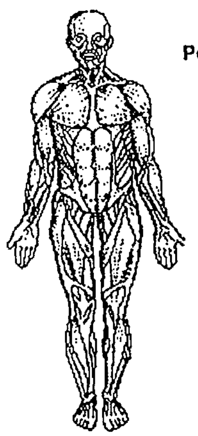
UNIT G: REVISITING SYSTEMS



Potential Activities:

- Microcosm Experiment
- Construction and study of EcoColumn
- the science of composting
- Sphere Interaction studies
- Aesthetics Field Trip
- Everything is Connected to Everything
- Field Studies Plots

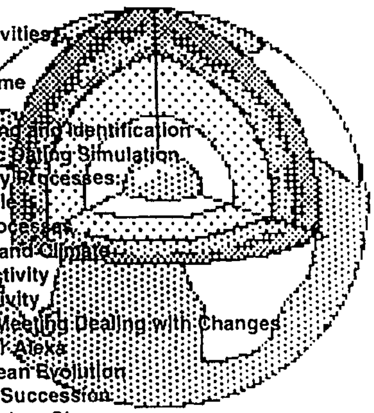
UNIT H: ORGANISMS AS SYSTEMS



Potential Activities:

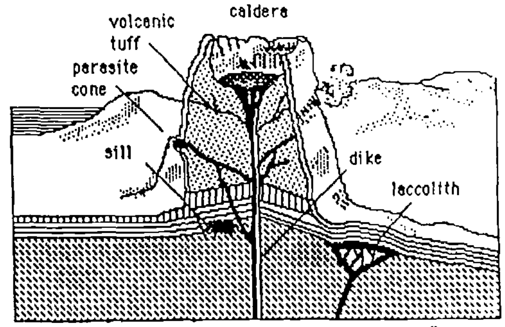
- Cell Structure and Function
- Cell Doctor
- Organelle Trade Show
- Protease Lab
- Catalase Lab
- Cell Energetics Hypercard Stack
- Organ Systems Project
- Cell Processes Games
- Biomechanics and Biceps
- Cell Model Building

UNIT I: THE EARTH AS A SERIES OF INTERACTING SYSTEMS

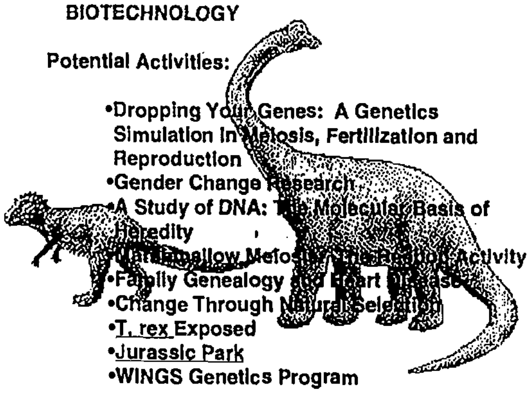


Potential Activities:

- Geologic Time
- Rock Cycle
- Fossil Making and Identification
- Radiometric Dating Simulation
- Sedimentary Processes: Stream Table
- Igneous Processes
- Volcanoes and Climate
- Ice Core Activity
- El Nino Activity
- Town Hall Meeting Dealing with Changes
- Downeaster Alexa
- Crustal Ocean Evolution
- Ecological Succession
- Climate System Changes
- "Great Quake of '89" Interactive Laser Video Disk



UNIT J: ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

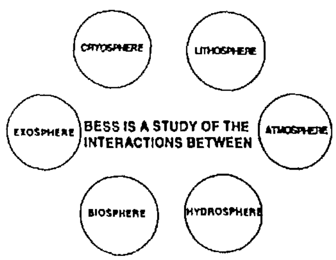


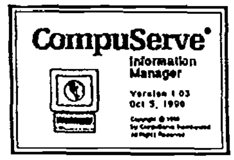
Potential Activities:

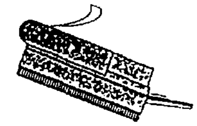
- •Dropping Your Genes: A Genetics Simulation in Meiosis, Fertilization and Reproduction
- •Gender Change Research
- •A Study of DNA: The Molecular Basis of Heredity
- •Marshmallow Meiosis: The Reaction Activity
- •Family Genealogy and Heart Disease
- •Change Through Natural Selection
- •<u>T. rex</u> Exposed
- •<u>Jurassic Park</u>
- •WINGS Genetics Program

UNIT K: CULMINATING ACTIVITY

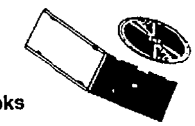
Students will be involved in a culminating activity which will explore and integrate many of the concepts and ideas developed during the second year of BESS.



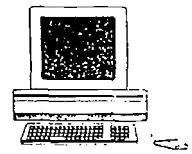


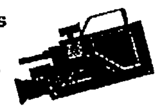


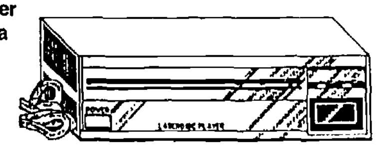
Support Materials:



- •Macintosh computers
- •Biology textbooks
- •Earth Science textbooks
- •Environmental Science textbooks
- •Microsoft Works
- •Hypercard
- •Superpaint
- •Computer simulations
- •Videotapes
- •Videodiscs
- •CD-ROM
- •DeltaGraph
- •OSU
- •School library
- •IBM compatible computer
- •Camcorder
- •Spinnaker Plus
- •Computer graphics
- •Computer sound editing capabilities
- •Periodicals
- •Atlases, almanacs, and dictionaries
- •BESS Library
- •Optical scanner
- •35-mm camera







EARTH SYSTEMS

a program description

Presented by Jerry Sherman

The Millbrook program in Earth Systems was developed by the Millbrook High School Science Department (4 teachers), in New York's Hudson Valley between 1991 and 1994. Earth Systems was approved by the State of New York as a Regents credit bearing course in June of 1994. It was fully implemented in September of 1994. Most elements of the course had been installed into the old Regents Earth Science course during the preceding school year.

Every ninth grade student it taking Earth Systems this year. There are presently 78 ninth grade students in the district. There is one Earth Systems teacher. Each class meets for 15 thirty eight minute periods each two weeks, having a double period every other day, for forty weeks during the year. Millbrook is the only school offering this locally developed course; there are several area schools who have inquired into our program, and are watching our progress.

The development of Earth Systems was supported with funding from a local grant. Before we received the grant, we were told by the granting officer, that there was a hesitancy to give us funding, because curriculum development does not bring about real change, it just rearranges the furniture. We were told that science teachers may know a lot of science, but do not have a feel for science. We were told strongly and clearly to develop a course which will give children that feel for science; a course which will significantly change the way in which children look at and see their world.

This has been our challenge and it has been our direction. While we certainly have not sacrificed substance for style, our methods and our philosophies have become the most important elements of Earth Systems. It is these elements that make the course relevant to children's lives. If you are restructuring your science curriculum, your greatest challenge will be to give your program a heart, a brain and a nervous system.

The four chambered heart of Millbrook's Earth Systems are our four core themes: chaos, global change, interactions and the Hudson Valley. These core themes weave all learning together, binding science to the children's lives and to the rest of their school learning. They give the student multiple structures on which to attach new learning. They help the student to build that feel for science and an appreciation for the world in which they live.

The brain of Earth Systems is the focus which we take and the techniques which we use to help the student to change their conceptual thinking. The nature of the human brain causes it to build understanding of concepts and of events with the imput which it receives. Each of our students has, as a result, a repertoire of misconceptions constructed by the brain from fragments of information long before they ever encountered a science teacher. Information from science teachers is generally simply added onto the misconception, the brain making sense of this new input as best as it can in the light of that existing misconception.

Millbrook's focus is on providing activities and discussions which will result in a revelations for the student. Only when the student is enlightened consciously, and put in a position of verbally stating his/her present understanding, can that student recognize their brain's faulty conception as a misconception. We understand that the misconception will remain in the brain; our task is not to eradicate it but to encapsulate it and to label it as a previous misconception. In the "Misconceptions Killed" section of our portfolio, students write: "I used to think that... but now I know that...", our prime method of verbalizing, encapsulating and labeling. The teacher monitors this section, finding the degree and the accuracy of each student's confrontation with and definition of misconceptions.

You should know that we have no assemblage of magical activities which will deal with misconceptions. We have a group activities which have varying degrees of success. We use these while we look for better ways of doing them, and while we look for better activities. We do not look for flashy activities, we look for effective activities. Horns, whistles and explosions do not have to occur in the classroom, they have to occur in the mind.

We give a pre-test and a post-test to measure students conceptual growth. It is the most telling, and the most important test that we give out students.

Our nervous system is our focus on the student. We are here, not for the subject matter, but for the student. The course, therefor, is not about science, but about the student. We are not here to "do" science, nor to act like scientists. We are here to empower students by taking the mystery out of the scientific world, by creating lifelong bonds between the students and their planet Earth, and by bringing the student security through understanding how the Earth works; by giving students a feel for science.

Students are given the tasks of reflecting upon their learning, and reflecting upon their progress. This reflection has several effects:

- *Students think more about what they do and of its importance to their lives. They no longer just do what is assigned because it is assigned.
- *The student self adjusts. In a progress statement, the student may comment on an area where they could improve. The likelihood now increases that the student will make that adjustment.
- *The student becomes more confident at self evaluation, and becomes less of a "risk" as an evaluator of his/her peers.
- *The student sees the teacher more as a learning coach, and less as an opposing force.

How is Earth Systems different from both the 1970 version of Regents Earth Science and the modified Earth Science program?

- Much more time is spent doing laboratory and field activities. Most learning occurs during the process of doing those activities.

- There is a focus on critical thinking and problem solving, higher order thinking skills addressed in both the district's and the high school's mission statements.

- The learning process is treated as continuum where all all new learning is interconnected with previous learning. All concepts are learned within a rich context. Learning is not treated as the accumulation of a collection of disassociated facts.

- Earth Systems integrates biology, chemistry and physics with the earth sciences, breaking down barriers which have artificially separated the science disciplines.

- The units are thematic in form, allowing a more natural learning of the interactions among the systems of this planet. This also leads to natural interdisciplinary efforts.

- Earth Systems is dynamic. As the world changes and as science changes and as technology changes, this course will change. 1990's Earth Systems will evolve into 21st century Earth Systems.

- There will be an alignment of the course material, the teaching delivery system and the assessments.

- The final assessment requires that student's have a considerable depth of understanding of the critical concepts. This will be true of all assessments. This reflects the high academic expectations which we will have of all students.

- Every student will take this course. There will be no school level course. We must lift our expectations of students of all abilities.

- The use of student portfolios will be a focal point of the course. The portfolio is a tool for student reflection on their own learning and for self assessment. The portfolio increases student-teacher communications regarding student progress. The portfolio enhances students' self-esteem. It is a record of student growth. Because students determine which pieces of work they will put into the portfolio, how they will be assembled, how they will be improved on, and much more, critical thinking is an important part of the portfolio. Interdisciplinary portfolio pieces are encouraged. Students have the opportunity to sail far beyond the scope of the course. And because portfolios can be shared, members of the community can gain broader understandings of student progress.

- Earth Systems follows the philosophy for change in science education championed by the American Association for the Advancement of Science, by the National Science Teachers Association, by the American Geological Institute, by the Program for Leadership in Earth Systems Education and by the New York State Curriculum and Assessment Council. Earth Systems is totally in keeping with *A New Compact for Learning's* vision of local development of curriculum, instruction and assessment.

Advance Earth Systems Science and Technology

MARPLE NEWTOWN SCHOOL DISTRICT
120 Media Line Road, Newtown Square, Pa. 19073
Alfred Capotosto

Implementation: The Fall Semester 1994

Goals : To gain a holistic understanding of the earth and its changing and interacting subsystems.

Grade level : 11,12 designed for academically talented students to take as an elective along with their advance placement courses.

Extent of use : District High School

Subject matter : Advanced topics that are studied include: the earth and the universe; matter and energy; satellites and their orbits; remote sensing instruments and image processing; the earth's atmosphere, lithosphere, hydrosphere, and biosphere.

Instruction/assessment : Inquiry approach (discover, problem solving, deductive reasoning, inductive reasoning, and discrepant events) along with demonstrations, lecture, and field trips. Evaluation is based upon the following measurements as appropriate; homework, written assignment, portfolio of images and independent studies, laboratory reports, chapter unit tests.

Strengths : A comprehensive approach to the curriculum which provides the student the opportunity to apply learned skills and concepts in a meaningful and worthwhile way. The students will use their literary skills to produce a living document that parallels the course and reflects their perspective for the Twenty-first century global society. Students will use the following technologies and software to open windows to processes operating within the holistic approach to Planet Earth:

1. 20 PC dos machines with inkjet printers
2. A direct readout station
3. Access to a real-time professional meteorological mainframe and database and graphics
4. Access to Internet
5. Softwar for qualitative and quantitative comparison of Landsat spectral bands.
6. Graphical Information System to examine and build databases.
7. N.I.H. Image Enhancement Software and CD Rhom for constructing and manipulating student constructed projects on 4 MAC machines.

Advanced Earth Systems Science and Technology
Marple Newtown High School
A Capotosto

PROJECT ExPEDITE
(Exploring Planet Earth by Developing
Imagery and Technology Education)

CREATIVITY/INNOVATION

The use of technology to remove the walls of a classroom so that the entire cosmos becomes the vista, an educational environment that is dynamic and not static.

DESCRIPTION

A comprehensive approach to the holistic study of the Earth which provides the individual the opportunity to apply learned skills and concepts in a meaningful and worthwhile way. An approach to the educational process that lacks any limits. The only restriction that exists is the individuals imagination and the will to follow that vision to its culmination.

NEED

Students must experience the technology which is shaping their word first hand. By permitting signals from satellites and the use of other current technologies to enter the classroom we will allow our students to feel that they are part of the educational process. When we permit them to contribute in a meaningful way then the educational process takes on a special and personal meaning.

UNCONVENTIONAL

It is possible to bring the "voices" of Russian and American satellites in real-time directly into the classroom. The signal coming from space immediately creates a captivating and exciting atmosphere for both the teacher and student. The thrust of this kind of situation causes the student to deal with reality in a real unconstrained way. This approach to the existing curriculum opens minds to the endless vision of possibilities, rather than one that stifles the ingenuity of an individual's mind .

APPROACH

The classroom/lab and technology available for this course includes the following the following equipment and programs to manipulate data:

1. 20 PC dos machines with inkjet printers.

2. A " Satellite Data Systems " direct readout station capable of receiving polar and geostationary transmissions for students to enhance and interpret their own images.
3. A modem with direct access to the " Accu-Weather's " mainframe for professional meteorological data.
4. Access to Internet for information that might be required to complete student generated projects.
5. The use of Eidetic Digital Ltd's. PEDAGeOG Scholar series program to manipulate Landsat Images from Eosat. The present images that are available are the fires of Yellowstone, Kuwait, the hurricane damage of Charleston,and the nuclear melt down at Chernobyl.
6. The Environmental Systems Research Institutes Inc. Graphical Information System with their " ArcView " product to build data bases.
7. Access to West Chester University's " Tiris " high resolution station.

The equipment is simplistic and does not require any special training to operate. The learning experience does not require another class or teacher to be doing the same thing at the same time. In some areas of the curriculum the "chalk and talk" may be the only approach. However, in other areas a simplistic approach to the use of technology provides the greatest degree of latitude and creativity for the student.

AREAS OF DEVELOPMENT

The following list are only possible suggestions to get started and should not be perceived to be limiting in form or topic. Applications can be found in Writing, Mathematics, Science,Social Studies, and Geography by developing critical thinking across the curriculum.

1. Measuring and organizing
2. Classifying
3. Concept formation
4. Reinforcing related educational goals
5. Identifying patterns and relationships
6. Formulating and testing hypotheses
7. Developing models to simplify, explain, and predict

8 An additional list of topics that deal with the students reflections or perspectives that could be included as possible suggestions to get started and should not be perceived to be limiting in form or topic.

a A biography on Dr. Stanley D. Shawhan a Marple Newtown graduate (class of 59') and world renowned scientist for whom our satellite center was dedicated by NASA' Space Physics Div. in memory of in 1991. What goals or a career could be inspired in a current student in M.N. based upon that which Dr. Shawhan was able to achieve after graduating from M.N.?

b. Compare and contrast Stan Shawhan's vision of the future as visioned in his 1959 graduating speech. Have recent graduation speeches of M.N. students reflected a different feeling for the future than viewed and held by Stan Shawhan when he was an M.N. student?

c. Essays on any topic covered in the Advanced Earth Systems and Technology course reflecting on technology and its impact on the planet and mankind.

d. Creative writing on any topic of interest that reflects the holistic fabric of Planet Earth. It will be your legacy to the next years class.

e. Poetry reflecting their feelings and views about what ever topic covered during the course they wish to share with other students.

NASA Classroom of the Future
Wheeling Jesuit College
Wheeling West Virginia

NASA Classroom of the Future Program (COTF)

Established by federal legislation in 1990, the mission of the COTF is to help improve the quality of science, mathematics, and technology education in the United States. The COTF is recognized by the West Virginia Department of Education as one of the West Virginia-based projects that provides resources such as instructional designs, assessments, model technologies, teaching modules, and pilot programs. The COTF develops exemplary multimedia curriculum materials, conducts applied research into teaching and learning with technology-based materials, offers model preservice and inservice teacher education programs, and conducts high-quality educational activities for students.

Housed in the Center for Educational Technologies the COTF Program, includes a software and multimedia development center, a "21st Century Learning Center," a NASA Regional Teacher Resource Center, a Challenger Learning Center, a Cooperative Learning Classroom, satellite/distance education facilities, video production facilities, experimental physics and chemistry laboratory, and a Discovery Center for interactive multimedia displays and hands-on science and mathematics activities. Most of these specialized areas within the facility will be used in teacher education programs, including the proposed Exploring the Environment program.

Since 1990, making use of existing Wheeling Jesuit College campus and school district facilities, the COTF staff has offered science and mathematics workshops to almost 1,000 teachers and over 10,000 students. Topics covered in workshops and classes have included "Forces of Flight," "Newton in Space," "Integrating Space into the Math/Science Curriculum," and "Heat and Energy." Summer institutes at COTF have included one- and two-week sessions focused on incorporating the National Council of Teachers of Mathematics (NCTM) standards into the mathematics curriculum and on incorporating astronomy, weather (via remote sensing), and aviation into the K-12 mathematics and science curriculum.

Astronomy Village

The COTF is currently beta testing the "Astronomy Village," a CD-ROM-based interactive multimedia program that places high school freshmen in the role of astronomers. Working in a cooperative setting, teams of students address one of ten problem-based scenarios. For example, the students may have to investigate stellar phenomenon that suggest the presence of a supernova. Assessment is largely based on student products such as reports and presentations. The "Astronomy Village" has been well received in demonstrations and is an excellent example of the design, development and implementation abilities of the COTF. This product will be available in Teacher Resource Centers in March 1995.

Exploring the Environment

The NASA COTF along with a consortium of partners from academia, state agencies, and industry, has signed a cooperative agreement with NASA Goddard Space Flight Center to develop educational Environmental Earth Science modules that demonstrate use of NASA's remote sensing databases.

NASA and associated agencies hold terabytes of remote sensing data in databases that can be used effectively to support educational activities over the Internet. Unfortunately, few teachers or students know of the resources or have the ability to access them. There are two purposes of this project: first, to develop eleventh-grade Environmental Earth Science course modules that capitalize on NASA's wealth of scientific, remote sensing information; and second, to deliver this information through the Internet — using *Mosaic* as the foundation for the interface design.

The primary objective of the Earth science modules will be to serve as a vehicle toward demonstrating effective educational uses of NASA's remote sensing databases. As Drury (1990) notes: "Remote sensing has several unique attributes. Foremost among these is the ability, through judicious use of the interactions between electromagnetic radiation and matter, to detect and in some cases to measure accurately the presence of a wide variety of phenomena, elements, compounds, and organisms in the oceans and atmosphere and at the land surface" (p. 165).

Taking guidance from the *Benchmarks for Science Literacy: Project 2061*, by the end of high school students will be expected to synthesize and evaluate such matters as: the cause and effect relationships of degradational and tectonic forces with respect to the dynamic Earth and its surface; the relationship of atmospheric heat transfer to meteorological processes; and the relationship between Earth processes and natural disasters. Interpreting the information will allow students to discover relationships concerning the weather and climate, the sea, the land, natural vegetation, human use of the land, and what might lie below the surface. Students should also be able to make and support insightful and informed recommendations to alleviate environmental problems. Use of this data in the modular, problem-based inquiry mode will allow students to analyze this data, to reflect, and to become science literate citizens.

As a nation, we could do better in preparing and supporting teachers. Examples cited in the May/June 1994 issue of *Teacher Magazine* provide a view of the challenge. For example, in his article *Start the Revolution Without Me*, Maeroff (1994) paints a picture of veteran teachers who have not seen or noticed signs of educational reform. Maeroff suggests that these teachers, who have been in classrooms for 20 years and are likely to be there 10 more, are part of the reason school reforms have not taken hold. Cited in the article is Mr. Romano, a veteran teacher about to retire. Mr. Romano indicates that he taught as he has been taught — implying that if these methods were good for him, then they should be good for the next generation. The COTF plans to help the next generation of teachers and the ones currently in the profession by providing workshops, preservice and inservice instruction, and on-line support materials.

To become knowledgeable citizens, our students need adequately prepared and equipped teachers. Summer workshops will be conducted at the COTF through 1997. Teachers will be provided the skills, knowledge, and methods necessary to use the modules in teaching students about Environmental Earth Science, to use technology as a teaching tool, and to become Teacher-Leaders, preparing other teachers to do the same. In addition to workshops, in the second and third year of this project, we will place on-line necessary information for using NASA remote sensing databases in the Exploring the Environment course modules, references to articles about exemplary teaching, information about other Internet resources, and ideas about implementing evolving science teaching standards and methodology.

During Year One the project will include the design of pilot Environmental Earth Science course modules that allow students to acquire understanding of Earth science through extended inquiry. In Year Two, the modules will be alpha tested in five West Virginia schools. As part of Year Three's beta testing, designed to demonstrate evolution to national application, the pilot materials will be evaluated in 17 high school classrooms over a six- state area.[1]

References

AAAS (1993). *Benchmarks for science literacy: Project 2061*, American Association for the Advancement of Science, New York: Oxford University Press.

Drury, S.A. (1990). *A guide to remote sensing: Interpreting images of the Earth.* New York: Oxford University Press.

Maeroff, G. (1994, May/June). Start the revolution without me. *Teacher Magazine*, pp. 38-45.

For further information about the Exploring the Environment Project or other COTF products, contact: Robert J. Myers Ph.D., Senior Instructional Designer, NASA Classroom of the Future, 316 Washington Avenue, Wheeling, WV 26003, (304) 243-2399, fax (304) 243-2497, myersb@cotf.edu.

[1] This project is supported by NASA through the "Remote Sensing Database Applications: K-12 Education" component of CAN-OA-94-1.

Dutchess County, New York
Statement of Progress

David Kibbler

The current program at Roy Ketcham High School is one of long tradition and proven ability to promote student growth and development in college. Our student population has, however, changed in past ten years. We now have a much greater percentage of inner city students and many more educationally handicapped students that need to be integrated into the traditional classroom by state law. With great grumbling our staff has come to the conclusion that the time has come for a radical change in format of instruction. Nothing will change in respect to the expectations of the student to learn the material presented or in depth of knowledge expected to be displayed at end of a course of study. What will change is the method and some of the content of instruction.

About 20 years ago a small group of teachers and an administrator started a program called Project Adventure to give the student with low self esteem an opportunity to show them selves that they had worth and could do those thing that made them fell better about themselves. Approximately 100 students each year were put into this program in ninth grade. Various outdoor character and esteem building activities were integrated with field studies of Earth Science. A team of teachers from the department of Science, English, Mathematics, Social Studies, Physical Education, and Guidance went on all field trips. Each subject area teacher was following a lesson plan concentrating on the science content, but which also had the students using all their other math, historical and language skills to answer the requirements of the field trip.

The program continues but has one great short coming, it lasts just one year.

With this historical precedent and the of the Project Adventure program of the past, it is proposed and the building administration has agreed to work toward a building wide Team Teaching Program to be implemented as a pilot program in the 1995-96 school year.

A group of ninth grade students will be picked at random, without regard to past achievement, placement, or ability and scheduled into the pilot program for two years (9th and 10th Grades). This cohort of students will be no larger than 125 and no small than 100. With this number of students each classroom teacher will have sections. The teachers in the pilot program will be resolved and only five class rooms will have lunch, a prep period and a free period to gather as a group, discuss the students progress, and plan for the next block of instruction.

THE TRADITIONAL LAYER CAKE EDUCATION OF THE STUDENTS WILL NO LONGER BE FOLLOWED. THE STATE EDUCATION DEPARTMENT WILL FULLY SUPPORT AN INTEGRATED

EDUCATION PROGRAM THAT IS WELL CONCEIVED AND EXECUTED. NATIONAL EDUCATION POLICY IS CHANGING AND WE NEED TO CHANGE TO KEEP UP WITH THE WORLD.

The group will be free of the traditional restraints on class time because they will have the flexibility to schedule to scheduling will allow for plenty of hands-on experiences in the field and traditional laboratory setting. All teachers will be able to show full length movies without spreading them over two days.

Large group lectures could be used by any subject area teacher as necessary.

The physical education teacher would have the assistance of one or two teachers on a rotating basis from the subject areas. Students would build physical education hours during the field trips to the local mountains and streams for science or historical investigations. A physical education teacher should be on the team.

Parents of the students to participate in this program will initially agree to commit their children to the two years of the program. Teachers selected will be volunteers that agree to teach for the full two years to keep continuity in the program and approach. The board of education will not jeopardize the tenure of any teachers who teach out their tenure area. They will extend tenure areas of those teachers willing to teach in two year team, and have done so for one cycle.

In short our school is going to try a radical change of method and approach thanks in no small part to the efforts of Drs. Mayer and Fortner. It has been a long and frustrating time coming but change is upon us at Roy C Ketcham High School. I only see good things coming from the efforts of the teachers and administrators now working to restructure our concept of how to educate our students. Thank you, all of you, for your time, efforts, patience, and most of all, for sharing your ideas.

Vision–Columbus' US!

Gloria Letts, Science Supervisor

Within the next decade, the Columbus Public Schools will become a dynamic urban system for mathematics, science, and technology education. Specifically, our system will be one where. . .

- *Every student in grades K-12 learns critical-thinking and problem-solving skills and is therefore prepared to function effectively in society and to become a life-long learner.*
- *The entire Columbus community is an interactive learning laboratory within which every resident (including students themselves) shares in the responsibility for math and science education.*
- *All educators (teachers, parents, business and social service leaders, and others) have access to data and training which allow them to effectively participate in the educational process and in the major decisions that affect that process.*
- *All Columbus area resources—human, financial, technological, and others—are coordinated and focused on increasing student learning of math and science.*
- *The education system itself has the capacity to ensure parity of educational opportunity for diverse groups of learners and to provide for ongoing reform in response to continually changing society and student needs.*

What We Plan to Do

This Implementation Plan for Columbus' Urban Systemic Initiative (USI) includes specific, proactive reforms that will change the performance of Columbus Public School (CPS) students over the next 5 years and beyond. Every element of our plan is designed to help us achieve one goal: to support all students in obtaining the mathematics, science, and technology skills they need to succeed in a highly competitive marketplace. In cooperation with the National Science Foundation and with numerous corporate and community partners, the Columbus Public School District will accomplish the following objectives by the Year 2000:

1. **Reengineer the Mathematics and Science Academic Program.** We will design an enhanced curriculum for all students that requires higher standards of achievement in core mathematics and science subjects, standards which surpass the national standards and state frameworks and result in the elimination of student tracking. To support students in achieving these standards, we will eliminate all remedial programs and in their place establish Mathematics and Science Academies, provide enrichment opportunities for every student, and implement a multi-faceted assessment program that will provide teachers with the information they need to modify their instruction based on each student's individual needs and to better inform parents of expectations and achievements of the student.

2. **Improve the Quality of our Professional Staff.** We will accomplish this through a comprehensive retraining program that includes a new Professional Development Academy co-developed by The Ohio State University and Columbus Public Schools, by instituting new policies for hiring and for evaluating our teachers and administrators, and by providing new mechanisms for input and decision making from our professional staff.

3. **Integrate Advanced Technology throughout the District.** We will provide tools within the classrooms that will allow students and teachers to access a wide variety of resources from throughout this community and beyond, enabling them to interact both with each other and with mathematics and science experts, libraries, and laboratories. New technology links will also advance the ability of our central offices and school buildings to access and share useful information.

4. **Strengthen Leadership and Accountability.** Our plan is to strengthen leadership and decision-making at the central office, building, and classroom levels. We will establish new positions within the central office to provide greater support to each school in the district. We will strengthen local control by empowering teams of teachers, administrators, and parents from each building in the district to develop a strategic plan and make decisions concerning the management of that site (hiring of mathematics and science teachers, instructional materials selection, professional development needs). These building-level strategic plans will provide the foundation for teacher and administrator goal-setting and evaluations. Submission of a strategic plan will make each Building Planning Team eligible to apply for a $5,000 USI grant which can be used by the school to begin implementing their own strategy.

How We Plan to Do It

Our driving goal during the 5-year USI Implementation is to provide a community-based educational structure that supports every student (regardless of race, gender, or socioeconomic status) in reaching higher levels of competency in mathematics and science. Each CPS graduate will have the problem-solving and reasoning skills to be successful in a college or other educational setting, or as a member of the workforce.

To meet each of the 4 objectives outlined above, we have planned multiple activities, some of which can be achieved in the short term, others requiring 5 or more years for full implementation. Because our vision requires a "cultural shift" to a new set of beliefs — that everyone, with hard work, can achieve high standards, and that everyone in the community has an important role to play in educating students — the first year of our initiative will focus primarily on:

- Developing detailed plans for each major change
- **Training** to prepare those expected to implement the changes
- Sharing plans and new expectations with the community through an **intensive communications/public relations campaign.**

Our plan involves a 3-year phase-in. During Phase 1, we will identify 12 schools (6,000 students-6 elementary, 3 middle and 3 high) which, beginning in the Fall of 1995, will become our initial "Schools of Excellence:". Using this concept will allow us to pilot and observe the various changes we are proposing, to evaluate the effectiveness of implementing those changes, and to make modifications, if necessary, before proceeding with the second phase of implementation (19 high schools, 10 middle schools, and 32 elementaries) during 1996-97. During that year, we will train other staff in the district, incorporating lessons learned from the Phase 1 implementation. By the start of the 1996-97 school year, our intent is to implement Phase 2 in another 61 schools, whose staff, through training, have shown readiness to proceed. The district will conduct the same type of careful evaluation of all 70 operating sites at the end of the 1996-97 school year, make adjustments, and be prepared to implement Phase 3 (all of the remaining CPS elementary and middle schools) by the 1997-98 school year.

What We Will Accomplish

Academic Achievement Outcomes

- Every CPS graduate will have had 4 years of high school mathematics and science and will have achieved, as a minimum, the performance standards set by the State of Ohio as 12th grade outcomes
- A district-wide plan will be used to evaluate promotion of students at grades 3, 5, and 8, based on successful completion of required standards using multiple assessment formats
- Intervention courses, both to enrich and remediate, will be offered through Mathematics and Science Academies, located conveniently throughout the community
- Discrepancy in the pass rates in mathematics and science courses based on race and socio-economic status will be reduced by 50 percent.

Professional Development Outcomes

- Teachers and administrators in the district will respond positively to the statement that all children can learn problem-solving skills
- Every professional staff member will have participated in focused professional development activities directly related to their own needs
- Every administrator and teacher will be evaluated using a process that includes multiple assessors and assessment instruments to direct areas of professional development need
- Integrated, interdisciplinary planning time will be incorporated into every school day.

Technology Outcomes

- Every school in the district will be linked together, to the central offices, and to a broad base of community resources to expand the school as a learning laboratory
- Every student will graduate with the technology skills to function effectively in either a college or other educational setting or in the workplace
- Every mathematics and science classroom will have 2 to 5 computers.

Management and Leadership Outcomes

- Every school will have a Building Strategic Plan aligned with the district's overall strategic plan and focused on that school's individual needs for professional development, instructional delivery, and staff hiring
- A central office support structure will be in place to help individual schools in preparing strategic plans and in acquiring funding resources to support their needs
- Permanent collaborative partnerships will be apparent throughout the district
- The community will be fully informed about and actively support the new set of higher standards and the changes in requirements for promotion and graduation.

Submitted by Gloria Letts, Columbus (OH) Public Schools

"E.S.E." into the Curriculum
---Integrating E.S.E. into the High School Classroom

Joan Dutt, Curriculum Consultant
South Dakota State Systemic Initiative

Earth Systems Education should be a vital part of a high school student's education. A South Dakota secondary teacher "ESE-rsized" her 8th grade Earth Science, and demonstrated how ESE could be infused in the high school Biology, Chemistry, and Physics curriculum. Examples of specific lessons using the Earth Systems Education philosophy were shared with the audience.

Activity Examples:

Biology/Environmental Science/Life Science

a. *Composting With a Wiggle*--An example of how worms can act as "organic garbage disposals." Students will see the role worms play in Earth systems cycles. (Fast Plants/Bottle Biology)

b. *A Heated Controversy*--Two "scientific" views of global climate change are given to students to demonstrate the uncertainty associated with controversial issues. (Adapted from "*A Heated Controversy,*" pp.45, 54, and 55 in Pollution: Problems and Solutions, *Nature Scope*, 1990)

c. *Prairie Populations*--Students apply their problem solving skills to a real life population. A variety of mathematical, language arts, and biological skills are integrated into the activity. (Dakota Projects)

Chemistry

a. *Typhoid Who? Mary or Larry?*--Students exchange unmarked test tubes of liquid which represent tainted and untainted solutions to help develop observational and interpretational skills which will help them to figure out where the original tainted solution came from.

b. *The Name is BOND - Chemical Bond*--Students classify compounds on the basis of physical properties.

Earth Science

a. *How Have All the Species Gone?*--This activity examines theories for the mass extinction of life forms and how they apply to evidence found in the geological record. (Adapted from Demise of the dinosaurs; A mystery solved? Robert S. Dietz. *Astronomy*. July 1991, 30-37, and others)

b. *Prairie Precipitation*--Using maps, students compare the rainfall, vegetation levels, and elevation levels of South Dakota. This activity is a good way to intriduce the concept of interrelatedness. (Adapted from "Rainfall and the Forest" in Project Wild 1987)

c. *Where Have the Birds Gone?*--A mapping activity that will allow students to discover where South Dakota birds spend their winters. (SDOU, 1991. The Birds of South Dakota. NSU Press, Aberdeen, SD, and others)

Physics/Physical Science

a. *The Physics 500* --Students engage in a variety of timed races and the results are used to calculate the average velocity.

b. *Barbie, Ken, and Sir Isaac* --This exercise introduces students to Newton's first law of motion.

c. *The All American Egg Drop* --Students design a container which will protect an egg from breaking upon the impact of a fall. This can be used to help explain the principle of Impulse.

d. *Can You Carry A Tune On a Bike?*--Students use the Doppler effect to calculate the speed of a vehicle as it passes.

Omaha Public Schools

North High Science Department Integration Proposal

Rationale: With the growing demand for science, math, and technology skills in our increasingly technological workforce, changes are necessary in the approaches to teaching in these areas to educate all students. Integration of disciplines, along with the teaming of teachers, have been demonstrated in the literature as addressing the needs of diverse student populations and leading to the graduation of life-time learners and scientifically literate citizens. According to Golner and Powell, "Interdisciplinary teaming has the greatest potential to benefit diverse groups - teachers, students, parents, and the school community...". Yager and Penick say, "We often give students only a small part of the big picture in education. There is a need for all to see the curriculum as a unified and well-orchestrated movement toward learning those skills and developing those attitudes that will produce a population of life-long, successful learners." It is the goal of the proposed program to unify disciplines in the science classroom, making content and process more meaningful to students and taking advantage of the areas of expertise of all staff members. Refer to the attached documents for additional information regarding benefits of integration and teaming.

Proposal Outline: It is proposed that, beginning in the 1994-95 school year, all North High students begin a two year integrated science program. This four semester course would integrate biology, chemistry, earth science and physics around central themes, with moderate integration of math and technology. Evenutally, the goal would be to include Social Studies and English in the integrated program. Pairs of teachers, one physical and one life science, would team to develop and teach these themes. Central strands would run through every theme in order to be reinforced throughout the two-year block. Expanded explanations of themes, strands, and teaming are found below. After satisfactorily completing the two year integrated block, students would have the option of selected specialized science curricula including Advanced Placement Biology, Advanced Placement Chemistry, Physics 3-4, Global Science & Technology, or Health Professions. The integrated program will be designed to address appropriate content and process outcomes to prepare students for any of these upper level course options.

Teaming: Assuming a 9th grade class of 700 students in 1994, there would be a need for approximately 32 sections (approximately 20 students each) of the 9th grade integrated class. We would like four sections offerred during each of eight periods. Two of these sections would be taught by current physical science teachers and two by current life science teachers. A life science teacher and a physical science teacher would team to develop themes and to teach them. They would be free to merge or trade their classes, in order for each teacher to teach to their area of strength. This would give students the best possible input from each teacher, and limit the stress under which each teacher would be placed by eliminating the need for them to teach outside of their trained discipline in this integrated course. The four teachers during a single class period would also be teamed. Two of the teachers would teach three themes and the other two would teach an additional three themes. They would shift classes periodically to reteach their themes to different students.

Process Skills: These skills are considered important hands-on and/or minds-on skills that all students should learn in introductory science courses.

Measurement	Biotechnology
Problem-Solving	Decision-Making
Observation	Graphing
Communication	Design

Content Outcomes: These are selected outcomes from the traditional science courses which will be mastered somewhere during the two year integrated course.

Biology Content Outcomes:

Biomes	Humans & ecosystems
Survey of Kingdoms	Human systems
Microbiology	Health & disease
Genetics & diversity	Evolution
Energy systems	Cycles

Earth Science Content Outcomes

Weather/Climate	Astronomy
Geology (Earth Forms)	Energy
Cycles	Radiation

Physics Content Outcomes

Work, Energy, Power	Sound & Light
Radiation	Force & Gravity
Planets	Machines
Electricity	Motion

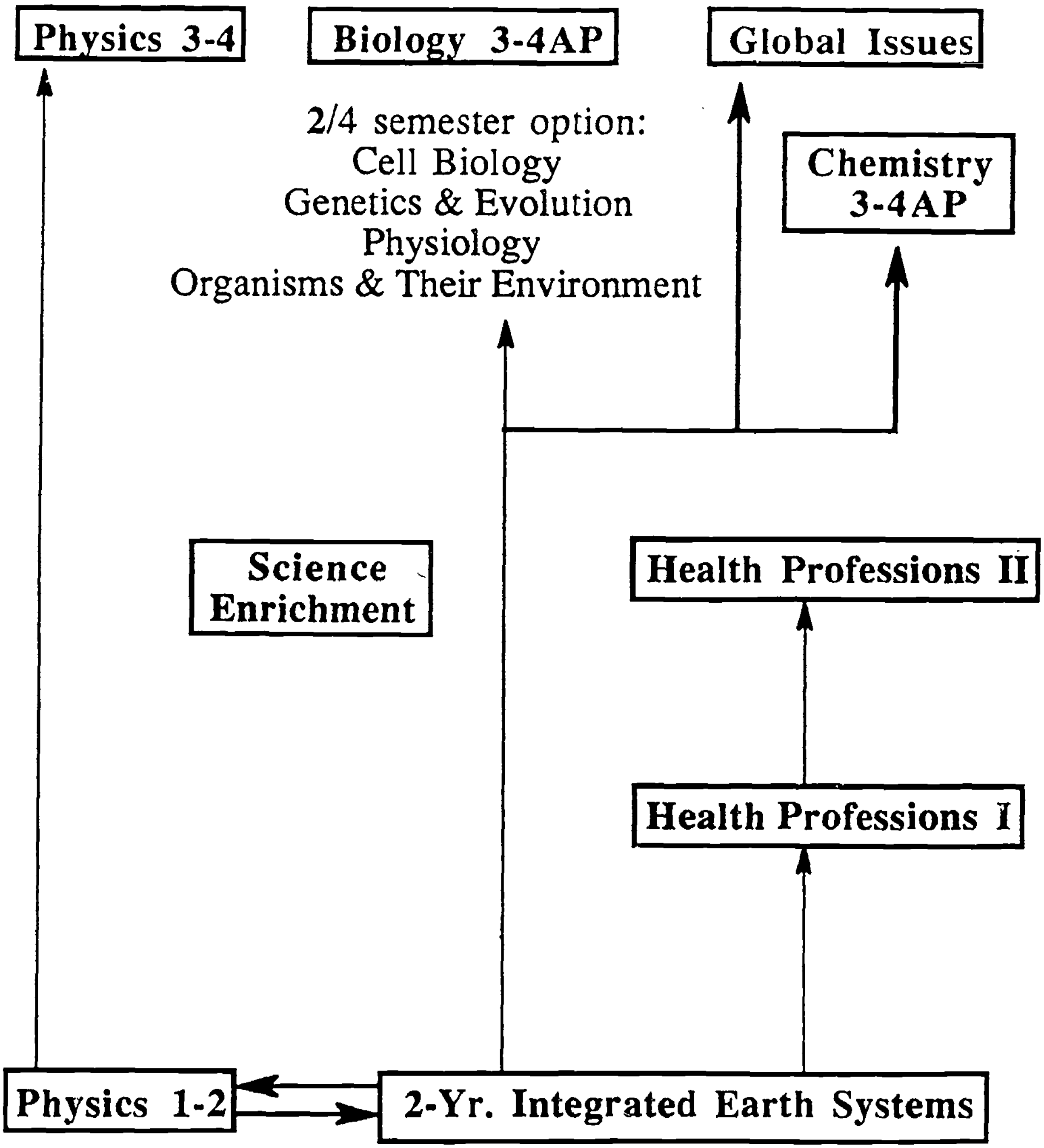
Chemistry Content Outcomes

Atomic Structure	Periodic Table
Gas Laws	Atomic & Molecular Structure
Stoichiometry	Chemistry

Strands: These are common threads which run through all of the themes and provide consistency to the course. These include important social skills and broad concepts which can be applied after graduation to college and/or everyday life.

Scale & Structure	Experimental Design & Technology
Energy	Patterns & Change
Systems & Interaction	Careers
Communication	Multicultural
Team Building/Cooperative Learning	

PROPOSED SCIENCE CURRICULUM OPTIONS



Gatewood 3

Possible Themes: Approximately six themes will be selected and developed for use with 9th graders during 1994-94 school year, and an additional six themes chosen for 10th grade during 1995-96.

Natural Disaster
Jurassic Park
Radon
Thermal Vents
Science Fiction
Water
Food Chemistry/Nutrition
Radon/Environmental Health
Biome Themes
Waste
UV-β Radiation
Sports Physiology
Music
History of Time
Space Flight

Technology Strand: It is proposed that one staff member be designated half-time technology support personnel during the initial year of the project. Approval has been given through the SPARCS project to release one teacher half time weekly. The remainder of the week would be used by this person to facilitate the training of students and science staff. Previous grant money and magnate money has been used to purchase hardware and software for use in the department. An proposal is in to establish two additional science/computer lab rooms. Training is essential to truly integrate technology as a strand in this program. This would provide maximum exposure of all students to technology and maximize use of available hardware and software. Some of the applications to be included follow:

Word processing
Graphics
Hypercard/Multimedia
Interfacing for data collection
Spreadsheet/Graphing
Pagemaker
Telecommunications

Integration Examples: Two examples which demonstrate possible integration of traditional content areas around a chosen theme follow:

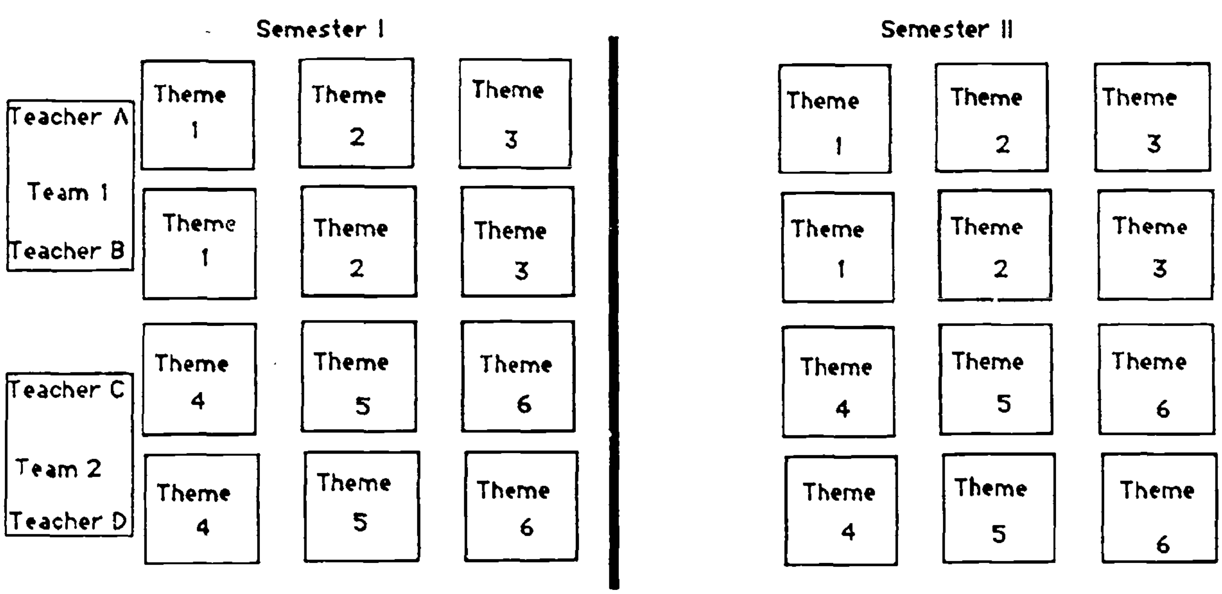
Community Water Quality

Water testing chemical
Water cycle
Solutions chemistry
Supensions
Basic waves
Universal solvent
Ecological aspects
Water use
Energy
Natural change
Organisms as indicators
Measurement levels
Mixtures
Flow rate
Acid rain/pH
Community cleanup
Surrounding community
Engineering & design (dams)
Ethics

Music (Wagner vs. rap)

Waves
Harmonics
Hearing
Patterns
Measurement
Physical/Medical
Pasqual's Triangle
Music Industry stuff
Design
Wave interference
Notation Systems
Problem solving
Sound
Fractions
Fibonacci Sequences
Ethical Issues
Materials Science

Teaming Logistics



Questions and Concerns Pertaining to Integrated Science

1. How does technology play a role in this new approach to learning science?

   Why
   Technology is a natural integration medium between science and math
   Need for technological skills in society today
   Technology is the tool of science in the field
   Opportunity, through technology, to access resources (database, scientists, other schools) via internet
   As a science magnet, important to integrate technology in all disciplines
   Opportunity for all ninth graders to access technology in a science setting
   Use of technology as a broader tool; not just a word processor, but a tool to both collect and analyze data

   How
   Current setting: With the one available science lab with computer setup, each ninth grade integrated class could cycle through once a week to use the computers in an experimental setting.
   Proposal: To add two more science labs with six computers each, so that all ninth graders could cycle through at least twice a week, using computers in experimental settings. We have already proposed the addition of these two lab setups, and are awaiting response from TechVision. It is also proposed to have a half-time technology paraprofessional or teacher to teach the computer applications to all ninth grade classes and the teachers of those classes. In that way, teachers will be trained to work autonomously during the following years.

2. How will universities and colleges view Integrated Science as meeting entrance requirements and interpreting a student's transcript. How can we prepare an explanation to accompany the transcript?

   Presently, the transcripts will read Biology 1/Chemistry 1 during the 9th grade year and Biology 2/Chemistry 2 during the 10th grade year. This is considered transitional until more colleges become familiar with integrated curricular offerings which are being created in many high schools and colleges.
   In the mean time, colleges are becoming familiar with the integrated move and are beginning to incorporate similar programs on the college level. As this becomes more common, we will be able to offer the course as Integrated Science 1-2 and Integrated Science 3-4 and show it as such on the transcripts.

3. How will the student who transfers in from another school be placed in the science program? How about the NHS student who transfers to another high school where Integrated Science is not offered.

Not to different from transfers now. Even now, movement from one teacher's class to another, or one school to another within a traditional discipline, does not guarentee easy transitions. Teachers teach in different ways and teach the concepts in different orders. Very rarely do we get transfers from other schools who are covereing the same content we are covering.

Other schools in district beginning to look to North for integration; some already integrating on a smaller scale

We can take any student from Bio, Chem, Earth Sci or Phys Sci and more easily take them through the transition to this course than from Earth Science, which we don't have, into Bio (or from any course currently not offered). In the same way, these students will have a strong process background, and a good background in each of the disciplines, that transition to another school into a traditional discipline should be possible.

4. How is honors credit going to be granted? On What basis? When does a student contract for honors or academic credit?

Students will contract for honors or academic credit according to the mastery of process skills and content knowledge. They will contract for this credit at the time they register for the course.

Portfolios will be established for each thematic unit. A folder will be designed for each theme which lists outcomes addressed in the unit, performance skills to be mastered, and levels of mastery required for both honors and academic credit. As students complete work, the skill or concept will be "checked off" on the folder indicating mastery.

5. How are lower ability students (typically fundamental students) going to be able to handle subject matter that pertains to Chemistry, Biology, Physical Science and Earth Science

They do currently cover the content.
Teachers will utilize cooperative learning and diverse strategies in the classroom, which better meet the needs of diverse student populations.
Roles and tasks assigned in the group settings can vary according to skills and abilities of the students in the heterogeneous groups. Students teaching students increases the knowledge base of both the student doing the teaching and the student doing the learning.
Enrichment activities can be utilized to challenge the gifted and remediate the students needing assistance.

Processes and concepts not mastered by some students, can be covered again or in a different way in a Science Enrichment class.

6. How does one respond to questions from parents of the very top knotch student who is looking for and demands challenging science courses. Will these courses be challenging?

   See # 5 above
   These courses will require that all students use higher level thinking skills, including problem-solving, decision-making, and analysis/synthesis of diverse content areas. This is more challenging, in many ways, than a traditional content directed course which stresses memorization of facts and regurgitation of these facts on a test, only to be retained for brief periods of time.

7. Are students going to be prepared well enough to take AP courses after two years of Integrated Science?

   Yes. Actually, they will be better prepared because of their broader base of science knowledge and skills.

8. Are we preparing students well enough to take the ACT and SAT tests?

   Yes....see #7.
   We will be teaching problem solving, analysis, data interpretation, and other higher level process skills which are currently emphasized on these tests. Not only should gifted students do better, but all students should do better.

9. Why is it so especially important to offer Integrated Science and not continue to offer the traditional Biology, Chemistry, Physical Science etc.?

   As the content bases of science disciplines grow rapidly, it is impossible to cover all of biology in biology, chemistry in chemistry, etc. The natural overlap between disciplines allows for more content coverage than in the discrete disciplines. As traditionally taught, many concepts were retaught year to year, but not in a synthesized manner. This way, the concepts can carry through the two year program, but in a more in-depth, synthesized manner.

   Integrating disciplines enhances comprehension of abstract science concepts. Concepts are learned in the way they exist in the natural world. As adults, we do not solve problems in terms of discrete disciplines; we solve problems utilizing our broad knowledge base. If students learn in this way, they will be more successful as adults.

   Offering both options would only create segration of students within the building; tracking would be further enhanced; this will allow all students to achieve to the level of their ability.

10. What special methods are teachers going to employ to assure success and/or motivate the lower ability students?

Already answered in several questions, specifically #5.

11. Pleaes list several of the themes of the course(s). What is going to be covered in Integrated Science?

See attached copy of themes in proposal outline. As further theme development occurs, we will keep you apprised.

12. What projects, extra research, papers etc. are involved for a student to work for honors credit?

Until these units are fully developed, we can not directly answer this question. However, current plans include natural extensions from each unit, rather than extra burdens or unrelated research projects tacked on and not applicable to the concepts being learned. An option can also be given for this extension to be semester or year long, which would allow for students to complete science fair projects or entries for other competitions.

13. Given the broad diversity of students abilities to be found in any given section of Integrated Science, will teachers end up with multiple preparations for each class?

No. All students will learn the same basic concepts and skills, with extensions created to allow for the gifted student. These units will be developed before the school year begins. Each pair of teachers will work on one unit, thoroughly develop the unit, and share it with the rest of the team. Each teacher will teach three themes twice during the year. This will allow for practice and modification, and limit the preparation required to deliver the course during the first year.

For more information, contact Kelly Gatewood at Omaha North H.S.
4410 N. 36th Street Omaha, NE 68111 or phone (402) 557-3400.

Submitted by Jon Yoder, Salem Oregon

FIELD BIOLOGY

SCOPE AND SEQUENCE:

UNIT 1. INTRODUCTION — SUGGESTED TIME LINE: 2 Weeks

TOPIC	OBJECTIVES	RESOURCE
	The student will be able to:	
Group Building	• display ability to problem solve through group interaction.	
Field Techniques	• demonstrate proper use of equipment, note taking, and field techniques.	

UNIT 2. WATER — SUGGESTED TIME LINE: 9 Weeks

TOPIC	OBJECTIVES	RESOURCE
	The student will be able to:	
Water	• identify the important characteristics, uses, and importance of water.	
Water Cycle	• construct a model and explain the steps of the water cycle.	
	• describe relationships between precipitation, runoff, and aquatic habitats.	
Mill Creek	• conduct a general stream survey.	
	• test water for essential water quality factors.	
	• photograph and map the stream.	
	• calculate stream flows and predict impact on humans and wildlife.	
	• identify aquatic organisms as indicators of water quality and as part of various food chains.	
	• inventory macroinvertebrates.	
	• explain the life cycle of the salmon and the difficulties maintaining adequate populations.	
	• identify the important components of a riparian zone.	
	• conduct plant and animal surveys in a riparian zone.	
	• analyze a variety of soil ecosystems.	

UNIT 3. WATERSHEDS — SUGGESTED TIME LINE: 7 Weeks

TOPIC	OBJECTIVES	RESOURCE
	The student will be able to:	
Mapping	• define and map a watershed.	
Ecology	• gain an understanding of the ecological concepts of energy transfer, population growth, and succession as they relate to the watershed.	

* explain the concept of biological diversity, provide reasons for conserving biological diversity, and the process by which biological diversity is lost.

END OF FIRST SEMESTER

UNIT 4. RESEARCH — SUGGESTED TIME LINE: 1 Week

TOPIC	OBJECTIVES	RESOURCE
	The student will be able to:	
Research Project	* develop skills necessary to conduct a major research project. * gain understanding on how to publish or present research project to the public.	

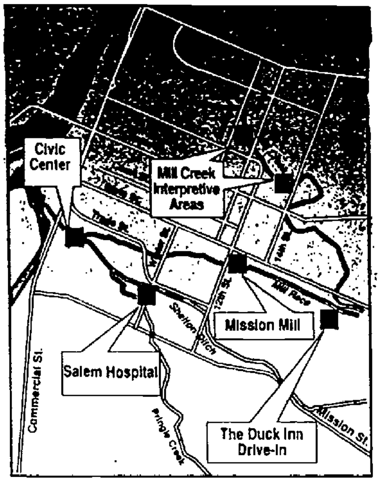
UNIT 5. HUMAN IMPACT ON THE WATERSHED — SUGGESTED TIME LINE: 10 Weeks

TOPIC	OBJECTIVES	RESOURCE
	The student will be able to:	
Land Use	* compare timber, agricultural, and urban areas and their impact on the watershed. * describe the government's role in land and water use.	
Endangered Species	* identify and describe factors that contribute to the endangering of species. * design a naterescaped area.	
Pollution	* explain the causes and effects of water, air, and soil pollution. * suggest ways to improve the environment.	
Energy	* compare the various forms of renewable and non-renewable energy. * describe energy conservation measures.	

UNIT 6. ISSUES AND ETHICS — SUGGESTED TIME LINE: 7 Weeks

TOPIC	OBJECTIVES	RESOURCE
	The student will be able to:	
Global Food Web	* discuss the positive and negative global effects of modernization, population growth, and resource distribution.	
Global Ecology	* explain how national self-interests and societal values and ethics influence international environmental issues.	
Local Issues	* examine local environmental issues from a variety of perspectives.	

Yoder 2



A Classroom Without Walls

The Mill Creek interpretive area utilizes an existing natural resource, Mill Creek, for a community - based, environmental laboratory at North Salem High School and the State Archives building. Teachers, students, and community members have created an innovative learning area that will educate students and the community about the fish, wildlife, plants, and water quality throughout the Mill Creek watershed. The riparian zone has been "naturescaped" to attract urban wildlife and the creek has been enhanced to provide new spawning areas for Fall Chinook. The opportunity to witness the migration and spawning of several thousand salmon occurs approximately the last two weeks of September. A paved trail, benches, signs, native plants, and an observation deck provide an informative setting to see and enjoy a natural area in an urban setting.

Salem Rotary Clubs

Partnership in Preserving Planet Earth

The Rotary theme "Preserving Planet Earth" has led to a commitment by the five Salem Rotaries to contribute $14,000 and join forces with North Salem High School in restoring life back to Mill Creek. The Salem Rotaries helped create an interpretive area that benefits all Salem citizens as well as visitors from outside the area. The Salem Rotary Clubs are commited to improving the quality of life for all humanity by helping to restore and enhance the world around us.

Be a Streamkeeper

Without your help, government agencies cannot protect and restore urban streams. Here are some things you and your neighbors can do today:

Don't waste water. Urban streams and rivers experience low summer flows with increased use.

Landscape with native vegetation. It requires less water, fewer pesticides and herbicides.

Revegetate stream banks with native plants. They anchor the soil and provide wildlife habitat.

Don't dump into storm drains. Motor oil, paint and other toxic materials degrade streams and wetlands. Stencil the "Dump No Waste, Drains To Stream" logo on storm drains (permission and supplies available from local agencies).

Avoid or limit use of herbicides, pesticides and fertilizers. They drain into ditches, storm drains, streams, wetlands and the groundwater.

Don't dump yard debris or grass clippings into ravines, ditches or streams. These organic materials rob a stream of its oxygen.

Report chemical spills or illegal dumping.

Adopt a stream or wetland. Form a "Friends" group to monitor, restore and preserve your neighborhood stream.

For Additional Information on Streams:
City of Salem - Pollution Control 588-6063
City of Salem - Public Works 588-6211
Mission Mill Museum 585-7012
Oregon Dept. of Water Resources 378-8455
Oregon Fish and Wildlife 378-6925
Oregon Dept. of Environmental Quality 378-8240

Mill Creek Interpretive Area

A Classroom without Walls

BEST COPY AVAILABLE

From the Field

CASE STUDIES IN ENVIRONMENTAL SCIENCE

To Teachers and Students:

This case study is one of a series produced by Concord Academy in collaboration with Earthwatch. Each case describes a specific environmental issue and provides information needed to develop answers to questions posed in the case. Each case also provides an opportunity to work on analytical, problem-solving, and critical thinking skills. For many of the issues raised in the cases there are no correct answers; any answer that is well supported by a careful analysis and logical interpretation of the information provided in the case is worthy of consideration. Additionally, each case allows students to learn how science and scientific inquiry can broaden understanding of our world and provide the basis for informed decisions on complex environmental issues.

The cases are typically divided into the following sections:

- *Background* Provides a context for the specific situation discussed in the case.
- *The Case* Describes the specific situation or problem.
- *Research Methods* Describes how the research was designed to examine the problem and how the work was carried out.
- *Results and Information for Analysis* Presents data collected by the researcher.
- *Questions for Analysis and Discussion* Provides questions to focus analysis and discussion on the problem raised in the case.

Data presented in each case were collected by scientists and volunteers, including the author, who participated in research expeditions supported by Earthwatch. Earthwatch, a not-for-profit organization, supports scientific studies around the world. Each Earthwatch expedition is under the scientific direction of a principal investigator. These investigators shared their data and assisted in the proparation of each case.

This project was supported by a grant from the Geraldine R. Dodge Foundation and by Concord Academy.

Dr. William S. Lawrence
Project Director, Concord Academy

Examples of Case Studies

From the Field: Ontario's Endangered Old-Growth Forest

The area known as the Temagami wilderness is located in the province of Ontario in North East Canada. This beautiful place is covered with a forest of White Pine and Spruce and dotted with numerous lakes. The inhabitants are few and the land is an important source of economic and often spiritual well-being to all of them.

Temagami is also a place where, as elsewhere in the world, people disagree over how best to use their natural resources. For the people of the Temagami region, their natural resources are forests, and forest resources are partly under the control of local inhabitants. Currently, as a result of the controversy surrounding the logging of White Pine forests, there is a moratorium on logging parts of the region. A newly-appointed Joint-Stewardship Council is now trying to reach an agreement on the best use of parts of the Temagami Wilderness. This land includes one-quarter of the area covered by old growth white pine forest.

In this case you will be asked to explore the perspectives of four different people, and then, acting as a member of the Council, reach a decision on two important issues. First, you will be asked to decide if either of two areas should be leased to lumber company for logging. To answer this question you will be given two sources of information. You will be given information from a diverse group of people interested in the fate of the Temagami wilderness; you will also be given information form an analysis on the effects of logging and forest preservation on the local economy. Irrespective of your decision, however, logging will continue in some parts of the region around Temagami. Therefore, your second decision requires you to use scientific data to recommend how the inevitable logging of stands should be conducted to maximize the regeneration of the trees which remain.

From the Field: Costa Rica's Endangered Sea Turtles

The endangered species known as the leatherback turtle bears the Latin name of *Dermochelys coriacea*. Covered with a centimeter of leathery skin, this shell gives the turtle its name. Unlike the characteristic dome shape associated with turtles, the leatherback has a low, hydrodynamically-efficient shell with 7 longitudinal ridges. An excellent swimmer, the turtle relies on jellyfish for nutrition. Since the leatherback has no teeth it cannot chew, but its back-pointing spines in its mouth prevent the jellyfish from escaping.

Major efforts are now being directed to preserve these important turtles. Unfortunately, until recently, a lack of information on the ecology of the turtles has made it difficult to arrive at informed decisions about the best way to insure their survival. What researchers have learned so far, however, tells us of the complexity of the reproductive process of these reptiles.

When the turtle eggs hatch, the mass of hatchlings scramble to the surface and wait for the cool night to emerge from the sand. Predators await them everywhere, from birds of prey by day to ghost crabs at night. After the successful ones reach the sea, they will become prey to new predators. While scientists do not know much about these predators, they do know that killer whales and large sharks attack the turtles; sometimes turtles are missing a part or all of one of their flippers. Dr. Paladino has even seen a female leatherback try to dig her egg pit with only a stub of one rear flipper. While she sometimes succeeds in her mission, at other times the maimed turtle cannot keep the hole clear of sand.

Humans, however, remain the major predator of these turtles. Turtles are often caught inadvertently in shrimp nets and fishing lines. Since turtles are reptiles they breathe air; although they can stay underwater for long periods, they cannot survive the deathtrap of fishing nets. Furthermore, in Costa Rica the leatherback's eggs are considered a delicacy. People collect them and sell them for substantial sums of money.

Since Playa Grande falls within an extensive park system, the leatherback nests and the eggs are protected. But only constant vigilance will guard the nests from poachers. In other parts of the world turtle nests are also threatened: Leatherbacks nest from Surinam and Guinea in South America to Ghana in Africa and Sri Lanka in the Indian Ocean. Some leatherbacks have made some amazing journeys; radio transmitters have tracked their course and found them in both tropical waters and the frigid waters above the Arctic circle. As cold as 5 degrees Celsius, these waters can freeze a human to death in less than 10 minutes. Because the turtles can maintain body temperatures 30 degrees above that of the water, they can survive even though they do not have the internal heat regulation system of mammals. One female tagged in Surinam was found 3,700 miles away in Ghana 11 months later. Unfortunately, researchers have been unable to discover as much information about male leatherbacks because they spend their entire lives at sea. Once they reach the ocean as hatchlings they do not come ashore again. They are unable to be kept in captivity because their drive toward the open sea leads them to collide continually with the walls of their container.

In this case, you, as one of Dr. Paladino's assistants, will be asked to evaluate data and make recommendations for turtle conservation.

From the Field: Managing Public Land: Too Many Deer?

There are over 350,000 square miles of publicly owned protected land in the United States. As a researcher at the Conservation and Research Center (CRC), located in Front Royal, Virginia, Dr. William McShea was well aware of the complexities of managing this vast public trust. Bill knew, for example, that at the Shenandoah National Park, next door to the CRC, park managers were required by law to maintain the abundance, diversity and ecological integrity of native plants and animals. And he knew, too, that park managers typically thought this meant that they should allow nature to take its course. But increasingly, Bill, along with many others, questioned whether letting nature take its course was necessarily the way to proceed. After all, he reasoned, while we may think of public lands as being wilderness areas, human activity on many public lands has resulted in habitats that are far from "natural." Ironically, it might sometimes require additional human intervention to restore these habitats so that the goal of maintaining diversity and ecological integrity is met.

As he contemplated how best to mange public land to maintain ecological and species diversity, Bill found himself thinking in particular of migratory birds. For years, bird watchers had observed that at their usual birding grounds there were increasingly fewer migratory birds, especially neotropical migrants. Their observations had been confirmed not long before when analysis of the Breeding Bird Survey (BBS), a long-term monitoring program coordinated by the U.S. and Canadian Fish and Wildlife Services, revealed that populations of many migrants were, in fact, rapidly declining. Neotropical migrants–those species that breed in North America, but spend their winters in Mexico and Central America–seemed to be especially vulnerable. In the eastern United States over 70 percent of the species migrating to the neotropics that are monitored by the BBS had declined over the last two decades. Bill felt that managers of pubic lands were legally required to address this serious problem, and that in this instance, the "let nature tale its course" approach did not seem to be working. Before action could be taken to solve the problem, however, it was clear that the exact causes of the decline in bird abundance needed to be determined.

There were many possible reasons for the decline of these birds. Not only do the birds have to migrate great distances to reach their wintering grounds in Central and South America, but once they reach the neotropics, these migrants must cope with the fact that millions of acres of their rain forest habitat has been destroyed. While it is tempting to blame the decline of neotropical migrants solely on changing patterns of land use in the neotropics, Bill realized that public land management practices in the United States might be contributing to the decline in forest-breeding birds.

The problem struck particularly close to home for Bill. Specifically, he knew that a common practice in managing forest communities in the eastern United States had been to maximize the populations of white-tailed deer. Predators had been removed, hunting limited, and habitats favorable to deer created and maintained. But the consequences of these policies on other species in the forest community had not been extensively studied. Was it possible, Bill wondered, that high deer populations were causing a decrease in bird populations? A mammologist by training, Bill decided to collaborate with Dr. John Rappole, an ornithologist, to try to determine the impact of high densities of deer on the abundance and diversity of forest birds.

Think of yourself as one of Bill's assistants to examine the data presented here and determine if white-tailed deer do have an influence on the abundance of forest understory birds. After interpreting the data, you will be asked to advise Bill on whether deer populations should be allowed to follow their "natural course" or if more active management is required.

Cases produced by Concord Academy in collaboration with Earthwatch.
Contact Dr. William S. Lawrence for complete materials.

NATURAL SCIENCE FIELD STUDY

AN EARTH SYSTEMS APPROACH TO INTERDISCIPLINARY EDUCATION

Ray Tschillard **Arvon Engel** **Dan Wagner** **Dan Warner**

University of Northern Colorado
University High School
Greeley, Colorado

As a result of numerous national studies during the decade of the 1980s, science teachers have become acutely aware that traditional delivery of science content does not reach many students. Consequently, several curriculum change proposals have been brought forward (AAAS Project 2061, NSTA Scope, Sequence, and Coordination, Program for Leadership in Earth Systems Education). The latter one, Project P.L.E.S.E. has been a nationwide K-12 curriculum reform philosophy piloted at teacher workshops at The Ohio State University and the University of Northern Colorado since 1990. PLESE was designed to infuse a systemic understanding of Earth into the curriculum content nationwide. Making the focus of the curriculum the planet on which we live helps to engage students where they are in the real world. This is opposed to trying to engage them in abstract or disconnected facts. Also, by focusing on students' feelings toward the Earth systems, the way in which they and others experience and interpret them, students are drawn into a systematic study of their planet. An aesthetic appreciation of the planet leads the student naturally into a concern for the proper stewardship of its resources; the PLESE approach capitalizes on students' awareness of their environment.

Trying to develop a concern for conserving the economic and aesthetic resources of our planet leads naturally into a desire to understand how the various subsystems function. A regard for how we study those subsystems also evolves. In learning how the subsystems function, students must master basic geology, physics, chemistry and biology concepts. Moreover, other disciplines are invited into the classroom simultaneously, instead of willful avoidance. Students are encouraged to make connections instead of just considering each subject in a void.

The curriculum change process in the nation's schools looms as a formidable barrier to school restructuring. New strategies are needed to convince teachers that there are better ways to develop an integrated curriculum that is both exciting to students and academically rigorous. Considering the school curriculum as a study of the Earth and its systems does provide a new paradigm for a relevant, engaging, and rigorous approach for integrating the sciences with art, literature, social studies, language, and other disciplines. Using the nationally-tested philosophy of the Program for Leadership in Earth Systems Education (PLESE), the University of Northern Colorado Laboratory High School Science Department proposed to model the "systems thinking" approach with a science course called "Natural Science Field Study." Our idea was to study a local river, the Cache la Poudre, as a system, using an integrated, interdisciplnary approach. Instead of teaching biology, geology, chemistry, and physics separately, it was the intent of the new class to allow students to learn and understand science concepts by analyzing a river system out in the field. Then once back in the classroom, students correlate the data to see how science disciplines are related to each other, as well as to all other disciplines. The premise of this effort is that solving global problems requires understanding the entire set of interactions between the various systems involved. The systems approach is in direct conflict with the reductionistic approach that instructs students in one narrowly-defined discipline at a time, and discourages connections to other disciplines.

Students study the Poudre River at three to five different sites. At each location, the students analyze the chemistry of the water, collect and identify aquatic organisms, label, analyze, and map the substrata of the river, and measure and calculate the physical characteristics of the river systems. Students are also asked to observe the aesthetics and stewardship of the river sites. An overall map is constructed of the study location and correlations are made to understand interacting systems.

Our purpose is to model a river system, the Cache La Poudre River, as a microcosm of global problems. By taking a concrete, local example of a study site, we have built a curriculum that can be transported back to each teacher's locality and applied to local systems in their communities.

There is a growing concern that schools are not recognizing the importance of how basic subsystems of the Earth can be correlated to an understanding of finding solutions to global problems. There is a need to evaluate and restructure the middle and high school curricula to ensure that present and future citizens will understand systems in a holistic manner.

The Lab School's Natural Science Field Study class is a systematic approach to the Cache La Poudre River, which has been recognized by the Colorado Division of Wildlife and the Colorado Audubon Society as an innovative and highly relevant course for today's students. This recognition has been emphasized by a strong interest from middle and high school teachers at national, regional, state and local presentations.

Natural Science Field Study

University of Northern Colorado Laboratory School

Arvon Engel Ray Tschillard

Dan Warner Dan Wagner

Goals:

- To provide experiential learning activities that maximize student potential while using a holistic approach around an academic focus.

- To develop inductive reasoning skills within an Earth Systems delivery model. (Understanding the whole by analyzing the parts)

Purpose:

- Our purpose is to model a river system, the Cache La Poudre River, as a microcosm of global problems. By taking a concrete, local example of a study site, we can build a curriculum which can be transported back to each teacher's locality and applied to local systems in their communities.

Outline:

- Application
- The radius growth is a function of experience, desire, feedback and application.
- Engage, explore, explain, extend.
- Activities.
- Base knowledge.
- River trips
- Guest speakers/Videos, Research projects, Journal Writing.

Evaluations:

- Test types and application (Equipment)
- Chemical tests.
- Biological tests.
- Geological tests.
- Water quality tests.
- Hydro-flow tests.
- Human impact tests.
- Aesthetics appreciation tests.
- Application/Correlations/Predictions/Questions /Solutions

Breaking down content barriers and teacher team building:

- More than a science program.
- Can not force content into the program.
- Teach the system.
- Look for a natural fit with the content - it is in there.

Program extensions:

- Leadership program.
- Planning time.
- Alternative assessment techniques.
- Multi-level, multi-age participants.

"ARE OZONE LEVELS AFFECTED BY ELEVATION, SEASONAL CHANGE, OR GEOGRAPHIC LOCATION?"

Jeffrey A. Samson
Gateway Regional High School
Littleville Road
Huntington, MA 01050

This ozone project was targeted for eighth and ninth grade Earth Science students from two adjoining school districts covering over two hundred and fifty square miles and including eight towns. Gateway Regional High School covers the largest area (seven towns) while White Brook Middle School represents the town of Easthampton. The project was implemented over the 1993-1994 academic year. The project's focus was discussion and exploration of environmental issues as they related to the atmosphere. Since the issue of ozone has gained worldwide attention, a project allowing students to actually observe environmental changes in their own community was anticipated to have a positive educational outcome. This project was used to enhance the curricula on Weather and Climate.

THE PROJECT GOALS

At the completion of this project, the student will be able to:

1. Use accurate research procedures.
2. Gather data from ozone test strips at different elevations and seasons.
3. Interpret data collected.
4. Assess the effects of ozone:
    a. during the seasons
    b. at different elevations
    c. at different geographic locations.

PROJECT DESIGN

Students from Gateway Regional and Easthampton School Districts monitored ozone for eight hours, five days consecutively during each of the four seasons. Each student was instructed to test for ozone levels on the same day and time at the various elevations within the school districts.

Materials used included:

1. Ozone sensitive color indicators
2. Ozone color comparison charts
3. U.S.G.S. topographic maps of the test area
4. Graph paper, multicolored pens, index cards, plastic bags, etc.

TEST PROCEDURE

1. Cut ozone test strips in quarters, labeling top and bottom. Attach individual test strips to 3 x 5 index cards using scotch tape. Label each index card with the following information:

-- student name
-- location
-- elevation
-- time
-- date

One quarter of each test strip indicator remained at school as a control.

2. Emphasize with students to keep test strip indicators in a resealable plastic bag until ready to be used.

3. On the designated test days and beginning at the same hour, remove indicators from plastic bag and place on a sunny side of their home at a height of five feet.

4. Following the same procedure, instruct the student to place a second test strip at another location of their choice at their home.

5. Upon completion of the eight-hour air exposure, have students place scotch tape over the test circle in order to stop the reaction. Return indicators to the plastic resealable bag. Remove all air before sealing.

6. Students were instructed to keep daily logs of the tests they performed, weather conditions, and any other variable they considered significant.

ANALYSIS OF DATA

Students were grouped geographically by towns. In each group, test strips were analyzed by comparing the color of the test circle to the ozone comparison color chart. The color charts allowed the students to analyze their test strip readings in parts per billion (ppb).

The students' first interpretation was that the ozone sensitive strips were inaccurate because there was a lack of significant color changes overall when students compared day against day, season against season. The students went about problem-solving and decided to compare paint chips available at local hardware stores to colors on their test indicators. This first alternative was not successful. The students then decided to design their own qualitative system using a rank order of one to four. One indicated a light color change (low level ozone) and four indicated a dark color change (high level ozone). This rating system was then used to interpret the data.

RESULTS

Students interpreted the data and concluded that the higher elevations had an 8 - 10% increase in the amount of ozone on the following dates which began their 5-day testing periods:

a. 9/22/93
b. 12/21/93
c. 3/22/94
d. 6/21/94
e. 6/22/94

Students also reported that the average ozone reading for Easthampton during one 5-day test cycle was 2.03 and the average for Gateway Regional during the same cycle was 1.31. The difference was possible due to students from two separate school districts analyzing their own results using their own formulas. This variance had been anticipated and inter-district communications had been established between Gateway and Easthampton science students through the telecommunication network. Students were encouraged to enter information regarding their data and exchange ideas related to the project. The Earth Science teachers from both districts met throughout the year to facilitate the project.

Finally, graphs and combined results indicated overall that 31% of all ozone readings were at level 2 and 69% were at level 1. The students were comfortable with their results, and concluded that ozone was not a health hazard during our testing dates.

PROJECT CONCLUSIONS

Students got a first-hand experience in the steps involved in a research project and its' procedures. Students began to realize that there are not always the optimum results strived for, and that new techniques needed to be devised. They became more proficient in graphing, interpreting these graphs, and analyzing the results.

Students were evaluated by participation in group discussions, analysis of graphs, and reviewing their results. A final brief written summary describing their experience with the project was handed in at the end of the academic year.

Next time, we would not space a project across the school year. The time element tended to cause a loss of interest for some. We might try to use a 5-consecutive-day period for testing instead. We would test strips ahead of time to verify their reliability. We found that the ozone sensitive test strips need to be improved by Vistanomics, Inc., Glendale, California.

Ozone awareness is becoming a health issue today. Having students gathering data and interpreting findings in this area of concern makes it a very realistic issue they can all focus on. We would like to continue experimentation in these areas of environmental concern to help students realize the importance of the Earth and its atmosphere to all of us.

OZONE

What is the fuss about these "ozone holes" over the Earth's poles?

What's so bad about auto emissions? and why do they make ozone?

What's so bad about chlorofluorocarbons? and why do they destroy ozone?

If ozone is bad for your lungs, why are we concerned that levels of it are decreasing in some places?

The Chemical Ozone

Ozone is a slightly bluish colored gas with a pungent smell. In fact the word comes from the Greek word *ozon* ($o\zeta\omega\nu$) meaning "smelling." You may have noticed the smell after electric sparks are produced (as in an electric train set) or sometimes when lightning strikes nearby. Ozone can also form from oxygen in the presence of ultraviolet light.

Ozone is a molecule made up of three atoms of oxygen, or O_3. The oxygen we breathe is actually molecular oxygen, or O_2. Normally at ground level there is very much less ozone than oxygen.

ATMOSPHERIC COMPOSITION

Gas	Percentage	PPB
Nitrogen (N_2)	78.084	780,840,000
Oxygen (O_2)	20.946	209,460,000
Argon (Ar)	0.934	9,340,000
Carbon Dioxide (CO_2)	0.033	332,000
Neon (Ne)	0.002	18,000
⋮		
Carbon Monoxide (CO)	0.000010	100
⋮		
Ozone (O_3) on surface	0.000004	40
Ozone (O_3) in stratosphere	0.0003	3,000
⋮		

Ozone is, however, a much more powerful "oxidizing agent" than oxygen, meaning it can react chemically with various substances adding an atom of oxygen to their molecular structure. Ozone is used industrially as a bleach and disinfectant because of its strong oxidizing ability. Whereas oxygen also causes oxidation, it is a much more stable molecule than ozone, which can more freely break apart to give up one of its atoms to another molecule. Oxidation in its rapid form is called combustion, so the "burning feeling" you get in your lungs when you breathe too much ozone is more or less just that—burning.

Ozone in the Stratosphere

One of the reasons ozone is normally so rare at the Earth's surface is that it reacts very rapidly with many different substances and is quickly destroyed. However, in the upper atmosphere, the air is thinner and there are fewer chemicals to react with, so ozone can persist in larger quantities for longer periods of time. Levels of ozone in the stratosphere (about 20 to 50 km up) can reach several parts per million.

The basic photochemical process was worked out in the 1930's by Chapman:

$$\textit{Ozone production} \quad \begin{cases} O_2 + UV\text{-}C \longrightarrow O + O \\ O + O_2 \longrightarrow O_3 \end{cases}$$

$$\textit{Ozone destruction} \quad \begin{cases} O_3 + UV\text{-}B \longrightarrow O + O_2 \\ O + O_3 \longrightarrow O_2 + O_2 \end{cases}$$

When the production and destruction rates are balanced, an equilibrium concentration of ozone is reached.

The ultraviolet photons come from the Sun, which emits about 10% of its power in ultraviolet photons. In fact the oxygen and ozone absorb so much energy in the stratosphere that it is warmer than most of the air except right at the surface. The ultraviolet photons that destroy oxygen and ozone in the photochemical reactions have different energies. Oxygen is so tightly bound together that it requires a very high energy UV photon. These are sometimes call UV-C photons. Such energetic photons are extremely dangerous to living organisms, but fortunately there's plenty of oxygen in the atmosphere to make sure that none of these reach the surface.

Ozone absorbs UV-B photons, which are less energetic, but still damaging to living organisms. Fortunately for life on Earth, the amount of ozone that normally exists in the stratosphere prevents most of the UV-B photons from reaching the surface. Remember, though, the level of ozone in the stratosphere depends on the balance of the production and destruction rates of the chemical reactions. If other destruction mechanisms begin to operate, the amount of ozone available to absorb the UV-B photons will decrease.

Photochemical Smog

At ground level, ozone can be created as a secondary byproduct of our combustion engines and even from fertilizers. When fossil fuels are burned at high temperatures (as in an auto engine), various levels of nitrogen dioxide (NO_2) and nitric oxide (NO) are created as a byproduct. Nitrogen dioxide can react photochemically to create ozone, and nitric oxide can react to destroy it by the following processes:

$$\text{Ozone production} \quad \begin{cases} NO_2 + UV \longrightarrow NO + O \\ O + O_2 \longrightarrow O_3 \end{cases}$$

$$\text{Ozone destruction} \quad \begin{cases} NO_2 + O \longrightarrow NO + O_2 \\ NO + O_3 \longrightarrow NO_2 + O_2 \end{cases}$$

Note that the ozone production is generally increased when there's more NO_2 and its destruction is increased when there's more NO.

Combustion produces both oxides of nitrogen, therefore we would have to study all the possible formation and destruction processes for NO and NO_2 to determine their equilibrium abundances in order to find the equilibrium concentration of ozone in turn. This is not a simple calculation! Results of detailed studies indicate that in the lower atmosphere ozone is increased by nitrogen oxide emissions, but in a more intense *UV* radiation field of the upper atmosphere, the balance may swing toward NO and hence to the destruction of ozone. This is why concerns were raised in the 1970's when it was proposed that we should build SST's that would fly in the stratosphere—there their nitrogen oxide emissions could *reduce* the ozone level.

Chlorofluorocarbons and Ozone

At last we come to the infamous hair spray problem. What have we done to change the balance of chemistry in the stratosphere?

The problem is a wonderful set of chemicals called chlorofluorocarbons (CFCs). As their lengthy name indicates, these are molecules that contain chlorine, fluorine, and carbon. Freon is a trade name for $CFCl_3$ and CF_2Cl_2, which are common refrigerants. CFCs are also used as solvents, propellants, blowing agents for plastic foam, etc.

CFCs are unusual in that they are not soluble in water and are chemically inert, so instead of being destroyed on the Earth's surface like most other chemicals we release, they gradually rise into the stratosphere. There the molecules are broken apart by the high-energy *UV* photons present.

The problem is with the chlorine that is released in the stratosphere. Chlorine *catalyzes* the destruction of ozone. Normally, there would be no more than a few tenths of a part per billion of chlorine occurring naturally.

$$\text{Ozone destruction} \quad \begin{cases} Cl + O_3 \longrightarrow ClO + O_2 \\ ClO + O \longrightarrow Cl + O_2 \end{cases}$$

The net reaction is a double-whammy since it removes both ozone *and* free atomic oxygen which could otherwise react to create ozone. Worst of all, since Cl is a catalyst, it is not destroyed in the process, so it is free to continue destroying the ozone.

The Antarctic (and Arctic) Ozone Holes

Why should the loss of stratospheric ozone show up in the arctic regions of Earth?

This is a complicated issue relating to several unusual aspects of the polar atmosphere. One aspect is the lower level of sunlight (on average) received at the poles. Normally, there is only about half as much ozone present in the polar stratosphere as over the equator. Also, after the long winter night, ozone levels are quite low because there has been so little sunlight for so long. Thus the polar atmosphere has a weaker (and more susceptible) ozone layer to begin with.

A second aspect of the polar atmosphere helps to increase the levels of free chlorine. Normally chlorine from CFCs can combine with hydrogen to form hydrochloric acid (HCl) which can reduce the amount of free chlorine available to destroy ozone. But on the surface of ice crystals in stratospheric clouds, the HCl reacts to unbind the hydrogen, leaving free chlorine, *and then* the ice can precipitate down to the surface, leaving lots of free chlorine.

All through the polar winter, the levels of chlorine in the stratosphere build up so that even with the coming of sunlight in the arctic spring, the rate of ozone production by *UV* photons just can't keep up with the destruction rate caused by the chlorine. As spring progresses into summer, the *UV* levels continue to rise, and finally the ozone hole closes, although this seems to be taking longer and longer each year.

The question is, is this a phenomenon that will remain isolated to the poles, or is it just showing up there *first*?

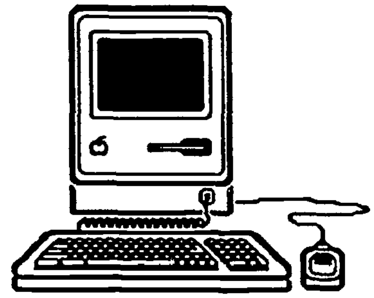
Further Reading

R. S. Stolarski, "The Antarctic Ozone Hole," *Scientific American*, January 1988

O. B. Toon and R. P. Turco, "Polar Stratospheric Clouds and Ozone Depletion," *Scientific American*, June 1991.

Submitted as a sample ESE teaching sample. Jeffrey A. Samson

Technology Presentations



Four participants shared information on new technologies available for ESE. While transcripts of these presentations were not developed, handouts and additional related information are included here. Readers are invited to continue to share technologies through the internet as they become available.

Robert Ridky of the University of Maryland demonstrated the Joint Education Initiative CD-ROMs. These were developed cooperatively by the US Geological Survey, NASA, and NOAA, using a wide range of data from these agencies. Image processing software helps students manipulate images to answer questions such as where will the coastline be if sea level rises a given amount. A brochure about JEI is included here.

Farzad Mahootian demonstrated access to internet resources and provided some user guidelines for effective searches. The GLOBE program has provided a guide to navigating the internet using Netscape software, finding and retrieving files, and saving reference sites for frequent "visits." A list of Universal Resource Listings (URLs) on Earth system topics, prepared by NASA and by GLOBE, is also included here.

Al Capotosto shared informational resources from NASA and demonstrated how teachers could obtain them. Al Lewandowski, PhD student on the Earth Systems Education staff, demonstrated the use of Hypermedia to display geographic information about some of the Great Lakes Areas of Concern. A CD-ROM with these materials, developed with support from the Great Lakes Protection Fund and The George Gund Foundation, will be available in 1996.

Joint Education Newsletter/Information Form

__: Yes, Please add me to the JEI NEWS Newsletter mailing list.
__: Please send me more information about Teacher Workshops
__: Please send me information about other JEI products & Services.
__: Yes - I want to become a corporate sponsor of a K-12 Teacher through JEI.

Name: ______________________________

Organization: ______________________________

Address:

____

____

____

City: ______________________ State/Province: ___

ZIP: ________

Country: ____________________

EMail: ____________________

Please Answer the following so we can serve you better:

Own a CD-ROM Drive?:____ Use EMail/Internet Services?:______

Type of Computer System Used: PC__ __ Mac_____ UNIX _____ NEXT _____

Ver of Operating System: DOS ____ OS/2 ___ Mac____

Please contact or send this form to:

JEI Staff
Robert W. Ridky
Director

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College Park, MD 20742-3281
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Fax: (301) 405-9377

Internet: jei@earthsun.umd.edu

Joint Education Initiative

The JEI 3-Disk CD-ROM Set

This 3 CD-ROM Educational software set was originally developed in 1990 at the US Geological Survey in cooperation with NOAA and NASA, as well as invited teachers and corporate sponsors. The philosophy behind this set of disks and all JEI products is that the best way to learn science is by doing science, no matter the grade level of the student. These CD-ROM's bring to the classroom the actual data and tools used by scientists in their research.

The Joint Education Initiative

The Joint Education Initiative is a NSF-funded project charged with teacher training and support for not only the JEI disks, but also other government published CD-ROMs and Internet Resources of interest to the K-12 education community. The Joint Education Initiative conducts an NSF-funded academic-year teacher workshop in College Park, Maryland, and summer institutes in College Park, Maryland, and Bellingham, Washington. On-site workshops can be arranged through the JEI office. The JEI office provides free technical support for both JEI products and other government-published scientific CD-ROMs. Other services include JEI-L, an Internet mailing list, Internet File Archives (via FTP), and a free newsletter.

JEI 3-Disk Set Contents

- Geophysics of North America
  - *Plotting of Earthquakes by location & intensity (1534-1985).*
  - *Graphical Adjustment of Sea Level.*
  - *Computer Generated Topographic, Magnetic, and Gravity Profiles*
  - *Mapping of Topographic, Gravity, Magnetic, Thermal, and Stress Data.*
- Total Ozone Mapping Spectrometer
  - *Gridded and Time Series of Ozone Data*
- SONIC: Seismogram Plotting and Analysis
  - *Numerous Station Recording From Around the World for Loma Prieta Earthquake.*
  - *Sampling of the world's earthquakes, October 1983.*
- Temperature-Salinity Profiles of the Pacific Ocean
- Antarctica: Three Views
  - *Using SMMR Images to show growth & recession of the Antarctic sea ice*
  - *AVHRR Imagery of the whole Antarctic Continent (1 km resolution).*
  - *MSS Imagery of Byrd and Koettlitz Glacier.*
- Voyager Imagery: Image Processing, Enhancement, and Interpretation
  - *Io Volcanic Eruption*
  - *Saturn's Rings*
  - *Loki Image*
  - *Miranda, Moon of Uranus*
  - *Saturn*
- GLORIA: Sea Floor Mapping
- Comets
  - *Comet Calibration Spectra*
  - *Comet Halley Spectra*
  - *Comet Giacobini-Zinner Spectra*
- Yellowstone Forest Fire
  - *AVHRR Imagery*
  - *Burn Severity*
  - *GIS Files (IDRISI)*
  - *NAPP Imagery*
  - *Old Faithful*
  - *SLAR Imagery*
  - *Thematic Mapper (Landsat)*
- Stars
  - *Revised Non-Stellar Objects*
  - *Solar Flares View File*
  - *Yale Catalogue of Bright Stars*

... and much more...

A Teacher's Activity Manual, developed by K-12 educators from around the country, with over 10 ready-to-use activities, is included.

System Requirements

IBM-PC® or Compatible

Hardware: 80286 or Higher / Hard Drive / 640 K RAM / CD-ROM drive / EGA Graphics (Super VGA Graphics Strongly Recommended).

Operating System: MS-DOS™ ver. 3.1 or higher / MSCDEX™ ver 2.0 or later. OS/2™ 2.x compatible.

A Mouse and 2 Meg or more of memory is recommended.

Macintosh®

Hardware: Color Graphics display / CD-ROM drive / 4 Meg RAM minimum

Software: System 6.0.5 or higher / Hypercard 2.0 or higher. SoftPC™ can be used to run most of the IBM-PC software.

JEI Order Form

Quantity ______ @ $34.50 (including Shipping and Handling)

Total Amount Enclosed .... $__________

Send Order Form with Check or Purchase Order Payable to *University of Maryland at College Park* to:

Office of Technology Liaison
4312 Knox Road
University of Maryland
College Park, MD 20742-5121
FAX: (301) 314-9871

Name: ____________________

Organization: ____________________

Address: ____________________

____

City: ____________ State/Province: ______

ZIP/Postal Code: _________

Country: ____________

About the World Wide Web

What Is It?

The **World Wide Web** is part of the **Internet**, which you may have heard referred to as the "information superhighway." The Internet is not so much a thing or a place as it is a process. It is a way for computers and their users all over the world to communicate with one another. In one sense, the Internet only exists because people participate in it. Because it is not a tangible thing or place, people sometimes refer to using the Internet as being in "hyperspace" or "cyberspace."

The World Wide Web (or simply the Web) is a portion of the Internet that is especially easy to navigate and use. There are several features that make the Web accessible even to people who have little or no experience with computers. The first reason is that there are special software programs called **browsers** that find documents for you on the Web. The browser does most of the work and takes care of the technical details for you. This lets you concentrate on where you want to go, not how to get there. Another advantage of the Web is that documents are given as "pages" that look very much like pages in a book, with easy-to-read typefaces and pictures. Perhaps the best feature of using the Web is that you have the ability to read through a document in a nonlinear way. If you are only interested in part of the information in a Web document, you can usually skip ahead to the "good parts" without having to read the parts that don't interest you.

How does it work?

Computers on the Internet communicate primarily through phone lines, using devices called **modems**. Once you have a modem and a phone connection to an Internet provider, you become part of the Internet. Using the phone lines, you can use the browser on your personal computer to request information from various large computers called **servers**. These servers let you read documents on your computer within seconds or minutes of requesting the information. In the case of the GLOBE data server, you also have to opportunity to send data to the server. Whenever you connect with a server on the Internet, your personal computer is called a **client**. In every "conversation" over the Internet, there is a client and a server. Some computers can be both clients and servers, but your personal computer will always act as a client.

To actually get to a document on the Web, you use your browser to make the connection. Every server the browser can contact (sometimes referred to as a **site** or **node**) has a unique address. You type the address and the browser will be able to find the right computer from among the thousands of computers on the Web. Web addresses are defined in a standardized way, known as the **Uniform Resource Locator** or **URL**.

Once the connection is made, the **Homepage** for that server will be displayed on your screen. TheHomepage is a sort of a welcome mat put out by the server. It gives you brief information about what you can find at that URL. It can take as much as several minutes for the page to be displayed, depending on how fast your modem is, how busy the phone lines are at that time, and how complex the **Homepage** is.

How do I use a World Wide Web document?

The first thing to keep in mind about reading documents on the Web is that there is no standard size for a "page." A page in a Web document is just a way to organize information that belongs together. You may not always be able to view the entire page at once, especially if you have a small screen. If you can't see all of the page, use the **scroll bar** on your browser to move down through the page.

As you look at a page in a Web document, you will see words or phrases that have been highlighted, for example in bold-faced type and underlined. These words are known as **hypertext links**, or links for short. When you use the mouse to click on one of these links, a new page appears on your screen. (The transfer to this new page can take a few minutes.) While the transfer is happening, you should be getting messages on the progress of the transfer, such as "host contacted, waiting for reply." This new page may have additional links. Sometimes the links connect you to a different computer that is far away from the computer where you started, maybe even in a different country. These hypertext links are the most powerful feature of the Web. Since the browser allows you to easily retrace the path you have taken, you don't have to remember the names and addresses of the pages you have seen in order to get back to where you started.

Downloading software on a PC

NOTE TO INSTALLERS: Please read all README files for software you are installing. These files often contain important information you may need to be aware of before installation.

⌧ Downloading Netscape 1.0N for Windows with FTP:

1. Open/Launch FTP (or Netscape) and type in FTP location (see list)
   Note: You can also try the http site - enter the same address beginning with http:// instead of ftp://
   Warning: This site is very busy and may require multiple tries before allowed login session
2. Login as anonymous user, if allowed
   Note: some FTP sites have you use your email address as your login
3. Screen will display **Current directory is /netscape/windows**
4. Scroll down until the files are displayed
5. Click one time on **ns16-100.exe**
6. A dialog box will appear asking **How would you like to handle this file?**
7. Place a formatted floppy disk into the floppy drive
8. Click on **Save to Disk**
9. Change the **Drive** to the floppy drive (probably A:)
10. Look for message for downloading completed
11. Exit FTP (or Netscape)

⌧ Installing Netscape 1.0N:

1. Verify that the floppy disk with downloaded Netscape file is in the floppy drive
2. Copy the file **ns16-100.exe** into a <u>temporary</u> directory
3. From Windows File Manager, click on the directory where you copied the Netscape file
4. Double-click on **ns16-100.exe**
   Note: This file is self-extracting and will put several other files into the directory
5. When the file extraction is completed, the File Manager will re-display
6. Press the F5 key to refresh the screen
7. Double-click on **setup.exe**
8. Install into **C:\NETSCAPE**
9. When finished, close the File Manager by selecting **File**, **Exit**
10. Double-click on the icon for Netscape to verify correct installation

Downloading software on a Macintosh

NOTE TO INSTALLERS: Please read all README files for software you are installing. These files often contain important information you may need to be aware of before installation.

⌧ Downloading Netscape 1.0N for Mac with FTP:

1. Open/Launch FTP (or Netscape) and type in FTP location (see list)
   Note: You can also try the http site - enter the same address beginning with http:// instead of ftp://
   Warning: This site is very busy and may require multiple tries before allowed login session
2. Login as anonymous user, if allowed
   Note: some FTP sites have you use your email address as your login
3. Screen will display **Current directory is /netscape/mac/**
4. Scroll down until the files are displayed
5. Click one time on **netscape.sea.hqx** (binhex format)
   Note: If you are downloading from Netscape, the file will be copied to your hard drive. You will need to move the file to a floppy, if desired.
7. Place a formatted floppy disk into the floppy drive
8. Save or Get File to the floppy disk
10. Look for message to verify download completed
11. Exit FTP (or Netscape)

⌧ Installing Netscape 1.0N:

WARNING: You MUST have UnStuffit to extract the file referenced below.
Note: If you are getting a copy of MultiSpec from GLOBE, it includes UnStuffit.

1. Double-click on file **netscape.sea.hqx**
   Note: Where the file is located, on a disk or on the desktop, is up to you
2. The file is self-extracting and will create a folder for Netscape automatically.
   If you used Fetch to FTP the file to your system, Fetch will automatically expand it as well.

Downloading Images from Netscape

ASSUMPTIONS:
- Netscape is open and running

⌧ On a PC

To DOWNLOAD or SAVE an image from Netscape

1. Display the desired graphic image on the screen
   Note: Only images that end in .GIF are downloadable
2. From the menu at the top of the screen, click on File
3. Select Save As
4. If desired, change to a different directory or drive
   Example: A: for floppy drive, or \NETSCAPE directory
5. In the lower left corner, change the Save File as Type to Source (*.htm)
6. Click on OK

To VIEW a previously downloaded/saved image

1. Launch/Open LVIEW by double-clicking the icon
2. Select **File, Open**
3. Double-click desired filename
4. When finished with LVIEW, select **File, Exit**

To DOWNLOAD or SAVE a Screen Shot in Netscape

1. Display desired screen image
2. Press the **Print Screen** button
   Note: This will take an exact "picture" of what you see on the screen, i.e. menus, toolbars...
3. Close or minimize NETSCAPE
4. Open/Launch LVIEW
5. Select **Edit, Paste**
   An exact copy of the screen from NETSCAPE will appear
6. To save this image, select **File, Save As**
7. Type in desired filename and file location, and click **OK**
8. When finished with LVIEW, select **File, Exit**

Where to find Software...

PC Software

Netscape 1.0N *WWW browser*
ftp://ftp.mcom.com/netscape/windows — File Name: ns16-100.exe

Lview *views pictures*
ftp://ftp.ncsa.uiuc.edu/Web/Mosaic/Windows/viewers — File Name: lviewp1a.zip

WHAM *plays sounds*
ftp://ftp.ncsa.uiuc.edu/Web/Mosaic/Windows/viewers — File Name: wham131.zip

MPEG viewer *shows movies*
ftp://ftp.ncsa.uiuc.edu/Web/Mosaic/Windows/viewers — File Name: mpegw32h.zip

Trumpet *allows dialup to access provider*
ftp://ftp.utas.edu.au/pc/trumpet/winsock — File Name: twsd20b.zip and winapps2.zip

Macintosh Software

Netscape 1.0N *WWW browser*
ftp://ftp.mcom.com/netscape/mac — File Name: netscape.hqx

JPEG viewer *views pictures*
ftp://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers — File Name: jpeg-view-331.hqx

Sound machine *plays sounds*
ftp://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers — File Name: sound-machine-21.hqx

Sparkle *shows movies*
ftp://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers — File Name: sparkle-231.hqx

InterSlip *allows dialup to access provider*
ftp://ftp.intercon.com/InterCon/sales/Mac/Demo_Software — File Name: InterSLIPInstaller1.0.1.hqx

Setting the Home Page in Netscape

ASSUMPTIONS:

- Netscape is open and running

⌧ On a PC:

1. From the menu at the top of the screen, click on **Options**
2. Click on **Preferences**
3. Change the category in the top box to **Styles**
4. Click the button for ⊙ **Home Page Location:**
5. In the white box, type exact URL Location for the desired Home Page
   Note: The GLOBE Program Home Page = http://www.globe.gov
   The GLOBE Student Data Server = http://globe.fsl.noaa.gov
6. Click **OK** at the bottom of the window to complete

⌧ On a Macintosh:

1. From the menu at the top of the screen, click and hold **Options**
2. Hold the mouse down, and select **Preferences**
3. Change the category in the top box to **Styles**
4. Click the button for ⊙ **Home Page Location:**
5. In the white box, type exact URL Location for the desired Home Page
   Note: The GLOBE Program Home Page = http://www.globe.gov
   The GLOBE Student Data Server = http://globe.fsl.noaa.gov
6. Click **OK** at the bottom of the window to complete

USEFUL URL ADDRESSES

GLOBE Educational Resources	http://rsd.gsfc.nasa.gov/globe1/educ.html
GLOBE HomePage	http://www.globe.gov/
GLOBE Student Server Page	http://globe.fsl.noaa.gov
The White House	http://www.whitehouse.gov/
NOAA Home Page	http://www.noaa.gov/
NASA Home Page	http://www.gsfc.nasa.gov/ NASA_homepage.html
EPA Home Page	http://www.epa.gov/
National Science Foundation	http://stis.nsf.gov/
Department of Education	http://www.ed.gov/
The President's Cabinet	http://www.whitehouse.gov/White_House/ Cabinet/html/cabinet_links.html
The Smithsonian	http://www.si.edu/
The Ohio State University	http://asp1.sbs.ohio-state.edu/
University of Maryland	http://metolab3.umd.edu/EARTHCAST/ earthcast.html
A Tour of the Planets	http://seds.lpl.arizona.edu/nineplanets/ nineplanets/nineplanets.html
Views of the Solar System	http://www.c3.lanl.gov/~cjhamil/ SolarSystem/homepage.html
The Jason Project	http://seawifs.gsfc.nasa.gov/ scripts/JASON.html
Live From Antarctica	http://quest.arc.nasa.gov/ livefrom/livefrom.html
The Journey North	http://ics.soe.umich.edu/ JourneyNorth/IAPHome.html
Explorer Home Page (Math/Sci Browser)	http://unite.tisl.ukans.edu/xmintro.html
ERIC on Information and Technology	gopher://ericir.syr.edu/11/Lesson/Science
The Geometry Center	http://www.geom.umn.edu/
The Weather Unit (for 4th grade)	http://faldo.atmos.uiuc.edu/ WEATHER/weather.html

USEFUL URL ADDRESSES (Continued)

ENC - Education, Math and Science Internet Sites	http://www.enc.org/enc/education.html
EOS - Earth Observing System	http://spso2.gsfc.nasa.gov/spso_homepage.html
University NAVSTAR Consortium (UNAVCO)	http://www.unavco.ucar.edu
University of Texas	http://wwwhost.cc.utexas.edu
Legislative information	http://thomas.loc.gov/
Star Trek WWW	http://generations.viacom.com/
Declassified images	http://eduwww.cr.usgs.gov/dclass/dclass.html
Netscape: How to Create Web Services	http://home.mcom.com/home/how-to-create web-services.html

Universities Space Research Association
Earth System Science Education Program

The Earth System Science Education Home Page

*** http://www.usra.edu/esse/ESSE.html ***
*** USRA Earth System Science Education Server ***

Education

http://spacelink.msfc.nasa.gov/
NASA Spacelink
telnet://spacelink.msfc.nasa.gov login: follow instructions
NASA Spacelink educational materials
http://198.76.12.2/ESSCC.html
Earth System Science Community Curriculum
http://www.teleport.com/~vincer/starter.html
Vince Ruggiano's Educational Resources
http://k12.cnidr.org:90/
EdWeb - Corporation for Public Broadcasting
http://hub.terc.edu/
The Eisenhower Regional Consortia - Science and Math Ed
http://www.ed.gov/
US Department of Education
gopher://isaac.engr.washington.edu/
IBM Kiosk for Education (IKE)
http://www.gsfc.nasa.gov/nasa_online_education.html
NASA Online Educational Resources
http://www.cua.edu/www/eric_ae/
ERIC Clearinghouse on Assessment and Evaluation
http://www.lerc.nasa.gov/Other_Groups/K-12/K-12_homepage.html
HPCC K-12 Home Page
http://sy2000.cet.fsu.edu:70/0/WWW/SY2000/Home.html
Schoolyear 2000 Home Page
http://seazar.jpl.nasa.gov/Edudoc.html
Education Resources - JPL
http://www.nceet.snre.umich.edu/listEd.html
Links to General K-12 Education Resources
http://thunder.met.fsu.edu/explores/explores.html
Florida EXPLORES! K-12 Meteorology
http://www.jpl.nasa.gov/educ/education.html
JPL Educational Outreach
http://seawifs.gsfc.nasa.gov/JASON.html
JASON Project
http://unite.tisl.ukans.edu/xmintro.html
Explorer Project, U of Kansas
http://tecfa.unige.ch/info-edu-comp.html
The World-Wide Web Virtual Library: Educ. Technology
gopher://ericir.syr.edu/11/Lesson/Science
Ask Eric Science Lessons (K - 12)
http://eryx.syr.edu/NASA/nasa.html
NASA Shuttle Imaging Radar - C Education Program

Selected Earth System Science Education Network Resources
For more information contact ruzek@usra.edu

http://www.gsfc.nasa.gov/nasa_online_education.html
NASA On-line Education Resources
http://guinan.gsfc.nasa.gov/K12/StarChild.html
The StarChild Project: Connecting NASA and K12
gopher://informns.k12.mn.us
K12 Gopher Info

International

gopher://gopher.gu.kiev.ua/
Ukraine Gopher
gopher://gopher.idrc.ca/
International Development Research Center
gopher://gopher.fao.org/
Food and Agricultural Organization
http://www.ns.doe.ca/how.html
WELCOME TO ENVIRONMENT CANADA'S ATLANTIC REGION
http://sunsite.unc.edu/sergei/Vnuki.html
Dazhdbog's Grandchildren - Russian Information
gopher://gopher.stolaf.edu/00/Internet%20Resources/US-State-Department-Trave
US State Department Travel
http://cen.cenet.com/htmls/Services.html
C.E.N. Technical Services - Commercial Russian Space Imagery
http://www.ices.inst.dk/
International Council for the Exploration of the Sea
http://tudedv.et.tudelft.nl/www/ttt/index.html
Telecommunication and Remote Sensing Technology, Delft
http://agcwww.bio.ns.ca/
Atlantic Geoscience Centre Home Page
http://www.dkrz.de/index-eng.html
The German Climate Computer Center, DKRZ
http://www.ns.doe.ca/how.html
ENVIRONMENT CANADA'S ATLANTIC REGION
http://iisd1.iisd.ca/
International Institute for Sustainable Development

Data

telnet://nssdca.gsfc.nasa.gov login: nssdc
NSSDC/Global Change Master Directory
http://gcmd.gsfc.nasa.gov/
WELCOME TO THE GLOBAL CHANGE MASTER DIRECTORY
http://www.civeng.carleton.ca/cgi-bin/quakes
Earthquake Information
http://ferret.wrc.noaa.gov/ferret/main-menu.html
Live Access to Climate Data
http://stardust.jpl.nasa.gov/pds-cn-homepage.html
Planetary Data Sysytem Central Node Home Page
http://stardust.jpl.nasa.gov/planets/
Welcome to the Planets

http://images.jsc.nasa.gov/html/earth.htm
Earth Observation Images - NASA JSC
http://www.esdim.noaa.gov:80/NOAA-Catalog/NOAA-Catalog.html
Welcome to the new NOAA Data Set Catalog!
http://ftp.clearlake.ibm.com/ERC/SSEOPhomepage.html
The ERC Earth Observation Images Database
http://www-lj.eb.com/survey/beta.html
Encyclopedia Britannica Online Beta Program
http://agcwww.bio.ns.ca/earth/earth.html
ROTATING EARTH IMAGE WITH GLOBAL RELIEF
http://sun1.cr.usgs.gov/landdaac/sir-c/sir-c.html
NASA SIR-C Survey Images
http://www.esdim.noaa.gov:80/NOAA-Catalog/NOAA-Catalog.html
The New NOAA Data Set Catalog!
http://images.jsc.nasa.gov/html/earth.htm
Earth Observation Images
http://ferret.wrc.noaa.gov/ferret/main-menu.html
Live Access to Climate Data
http://www.ngdc.noaa.gov/mgg/aboutmgg/wdcamgg.html
World Data Center A for Marine Geology & Geophysics
gopher://atm.geo.nsf.gov/11/weather/Rest_of_World
Electronic Weather Maps of the World (UNIDATA IEIS)
http://atm.geo.nsf.gov/
NSF Geosciences Unidata Integrated Earth Information Server (IEIS)
http://java.meteor.wisc.edu/index.html
University of Wisconsin - NMS Home Page (Vis 5D forecasts)
http://topex-www.jpl.nasa.gov/
Topex-Poseidon Home Page
http://seazar.jpl.nasa.gov/
JPL Physical Oceanography DAAC Home Page
http://xtreme.gsfc.nasa.gov/
AVHRR Pathfinder Home Page
http://southport.jpl.nasa.gov/
NASA/JPL Imaging Radar Homepage
http://wwwdaac.msfc.nasa.gov/wetnet.html
The WetNet Project
http://info.er.usgs.gov/
The USGS Home Page
http://www.ngdc.noaa.gov/whatsnew.html
The National Geophysical Data Center
http://www.grdl.noaa.gov/
NOAA Geosciences Laboratory
http://pathfinder.arc.nasa.gov/
EOS Pathfinder Datasets
http://www.ucar.edu/
National Center for Atmospheric Research
telnet://glis.cr.usgs.gov login: follow instructions
EROS Data Center Geographic Land Info System
gopher://gopher.ngdc.noaa.gov
NOAA Geophysical Data Center
gopher://gcdis_gopher.esdim.noaa.gov
Global Change Data server

ftp://diamond.ssec.wisc.edu
GOES Pathfinder browse images
ftp://aurelie.soest.hawaii.edu
GMS imagery
ftp://manono.gsfc.nasa.gov
Ocean color data
ftp://jwocky.gsfc.nasa.gov
TOMS ozone data
ftp://huntress.jpl.nasa.gov
Earth, space science data
ftp://sseop.jsc.nasa.gov User: photos PW: photos
Hand-held photos of Earth
ftp://explorer.arc.nasa.gov
GOES and GMS images
ftp://hurricane.ncdc.noaa.gov
NOAA climate archives
ftp://shrimp.jpl.nasa.gov
Physical oceanography data
ftp://nasagiss.giss.nasa.gov
GISS cloud climatology data
ftp://daac.gsfc.nasa.gov
GSFC EOSDIS data

News/Newsletters/Updates

http://server.uwindsor.ca:8000/~fung6/tn.html
Typhoon News
http://www.jpl.nasa.gov/jplnews.html
Recent news from JPL
http://finger recent@eqinfo.seis.utah.edu/HTML/SeismicityMaps.html
University of Utah recent seismicity maps
http://aps.org/
The American Physical Society
http://rs560.cl.msu.edu/weather/getmegif.html
Weather Maps To Go - Michigan State
http://www.jpl.nasa.gov/jplnews.html
Recent news from JPL
http://newproducts.jpl.nasa.gov/calendar/calendar.html
Space Calendar
http://www.gsfc.nasa.gov/hqpao/hqpao_home.html
NASA Public Affairs
gopher://ftp.voa.gov/
Voice of America News
http://www.atmos.uiuc.edu/
U of I - The Daily Planet
http://images.jsc.nasa.gov/html/pao.htm
NASA press release photos
gopher://chiphead.ndsu.nodak.edu
NASA News Archive
ftp://pubinfo.jpl.nasa.gov
JPL public info/images

USRA

Universities Space Research Association
Earth System Science Education Program

Lists

ftp://rtfm.mit.edu/pub/usenet/news.answers/weather/data/part1
Ilana Stern's excellent weather information list
http://www.city.net/
City.Net - Worldwide city information
http://info.cern.ch/hypertext/DataSources/WWW/Servers.html
Web Server Lists
http://www.ccsf.caltech.edu/~roy/others.html
Hot Hot List from Caltech
http://galaxy.einet.net/galaxy/Science/Geosciences.html
Einet Geosciences List
gopher://psulias.psu.edu:70/11%5B_shelves._subject._earthsci._global%5D
Global Change Bibliography
http://www.picosof.com:8080/html/scott.html
The Scott List
http://www.info-mine.com/
INFO-MINE
http://twinbrook.cis.uab.edu:70/webNews.80
webNews
http://agcwww.bio.ns.ca/misc/geores/sotw/sotw.html
Scott's Earth Science Site of the Week
http://galaxy.einet.net/galaxy/Science/Geosciences.html
Geosciences (Science)
http://www.clark.net/pub/listserv/listserv.html
LISTSERV Home Page
http://jacobson.isgs.uiuc.edu/
DINO RUSS's HOME PAGE
http://www.englib.cornell.edu/geology_resources/ORES/earthscience.html
On-Line Resources for Earth Scientists.
gopher://una.hh.lib.umich.edu/00/inetdirsstacks/environment:murphybriggs
Murphy-Briggs Guide to Environmental Resourceson the Internet
http://white.nosc.mil/info.html
The Planet Earth Home Page (Navy)
http://http2.sils.umich.edu/~lou/chhome.html
The Clearinghouse for Subject Oriented Internet

Information Technology

http://www.microsoft.com/
Microsoft Corporation
http://www.dartmouth.edu/pages/TidBITS/TidBITS.html
Macintosh TidBits - Adam Engst
http://zcias3.ziff.com/%7Emacweek/
MacWEEK Home Page
http://info.cern.ch/hypertext/WWW/Provider/Overview.html
How to put your data on the web
http://www.info.apple.com/
Apple World Wide Web Home Page
http://rever.nmsu.edu/~elharo/faq/Macintosh.html
The Well Connected Macintosh

ftp://wuarchive.wustl.edu
Washington University oftware archive
ftp://mac.archive.umich.edu
U of Michigan Macintosh Software archive
ftp://ftp.ncsa.uiuc.edu
National Center for Supercomputing Applications Archives
ftp://ftp.apple.com
Apple Computer archives
ftp://sumex-aim.stanford.edu
Macintosh software

Weather/Climate

ftp://rtfm.mit.edu/pub/usenet/news.answers/weather/data/part1
Ilana Stern's excellent weather information list
gopher://wx.atmos.uiuc.edu
U of Illinois Weather Machine
gopher://groundhog.sprl.umich.edu
University of Michigan BlueSkies Weather server
http://rs560.cl.msu.edu/weather/getmegif.html
Weather Maps To Go - Michigan State
http://www.epri.com/Strategic/VitalIssues/MECCA/MECCA.html
Model Evaluation Consortium for Climate Assessment
http://www.dkrz.de/index-eng.html
The German Climate Computer Center, DKRZ
http://ferret.wrc.noaa.gov/ferret/main-menu.html
Live Access to Climate Data
http://thunder.met.fsu.edu/explores/explores.html
Florida EXPLORES! K-12 Meteorology
gopher://atm.geo.nsf.gov/11/weather/Rest_of_World
Electronic Weather Maps of the World (UNIDATA IEIS)
http://atm.geo.nsf.gov/
NSF Geosciences Unidata Integrated Earth Information Server (IEIS)
http://java.meteor.wisc.edu/index.html
University of Wisconsin - NMS Home Page (Vis 5D forecasts)
http://noaacdc.colorado.edu/cdc/cdc_home.html
NOAA Climate Diagnostics Center
http://rs560.cl.msu.edu/weather/index.html
MSU archived weather loops and images
http://www.ucar.edu/
National Center for Atmospheric Research
gopher://meteor.atms.purdue.edu
Purdue University Weather Processor
gopher://gopher.ssec.wisc.edu
UW - Madison Space Science and Engineering Center
ftp://madlab.sprl.umich.edu
U Michigan Blue-Skies software
ftp://hurricane.ncdc.noaa.gov
NOAA climate archives
gopher://psulias.psu.edu:70/11%5B_shelves._subject._earthsci._global%5D
Global Change Bibliography

Government

http://thomas.loc.gov/
THOMAS: Legislative Information on the Internet
gopher://kraus.com/
Government Publication Network
gopher://gopher.legislate.com/
Legislate Gopher
http://policy.net/
Policy.Net - A Guide to the US Congress
http://lib-www.ucr.edu/govpub/
Government Information Resources

Professional Organizations

gopher://gopher.nserc.ca/
Natural Sciences and Eng Research Council of Canada (NSERC)
gopher://gopher.fao.org/
Food and Agricultural Organization
http://cass.jsc.nasa.gov./CASS_home.html
Center for Advanced Space Studies CASS Home Page
http://www.iris.washington.edu/
Incorporated Research Institutions for Seismology
http://www.ieee.org/
IEEE Home Page
http://newton.otago.ac.nz:808/trol/Rolhome.html
Radioscientist On-Line homepage
http://gtri.harc.edu/
Geotechnology Research Institute
http://www.tagsys.com:80/Ads/USIS/
United Societies In Space Home Page
http://www.aescon.com/geosociety/index.htm
Geological Society of America
http://www.lib.uwaterloo.ca/society/overview.html
Overview of the Scholarly Societies Project
http://aps.org/
The American Physical Society
http://sunrae.uel.ac.uk/palaeo/index.html
International Organisation of Palaeobotany
http://www.ma.hw.ac.uk/RSE/
Royal Society of Edinburgh
http://www.geo.ed.ac.uk/home/gishome.html
GIS WWW Server Home Page
http://aps.org/
The American Physical Society
gopher://cause-gopher.colorado.edu
http://cause-www.colorado.edu
CAUSE

Commercial

http://www.theworld.com/travel/travelag/planit/agent.htm
TheWorld® - Carlson Travel
http://www.fisher1.com/
The Fisher Scientific Internet Catalog
http://www.carl.org/carl.html
CARL Corporation - Network of libraries and databases
http://cen.cenet.com/htmls/Services.html
C.E.N. Technical Services - Commercial Russian Space Imagery
http://www.service.com/stv/
Science Television
http://www.elsevier.nl/catalogue/Menu.html
Elsevier Science catalogue
http://www-mitpress.mit.edu/
The MIT Press

Government Agencies

gopher://vm1.hqadmin.doe.gov/
Department of Energy Gopher
http://pampas.cr.usgs.gov/Welcome.html
U.S. Geological Survey, Branch of Geophysics Home Page
http://atsdr1.atsdr.cdc.gov:8080/cx.html
Agency for Toxic Substances and Disease Registry Science Corner
http://www.usno.navy.mil/
The U.S. Naval Observatory (USNO)
http://www.dtic.dla.mil/dtiw/
Defense Technical Information Web
http://www.epa.gov/
Environmental Protection Agency WWW Server.
http://www.noaa.gov/nesdis/nesdis_intro.html
NOAA NESDIS
http://resources.agency.ca.gov/
CERES - California Environmental Resources Evaluation
http://www.census.gov/
US Bureau of the Census
http://info.er.usgs.gov/
The USGS Home Page
http://www.ngdc.noaa.gov/whatsnew.html
The National Geophysical Data Center
http://www.grdl.noaa.gov/
NOAA Geosciences Laboratory
http://noaacdc.colorado.edu/cdc/cdc_home.html
NOAA Climate Diagnostics Center
telnet://fedworld.gov login: follow instructions
Federal infromation from STIS
gopher://info.er.usgs.gov
USGS information server
gopher://stis.nsf.gov
NSF's Info Server
ftp://stis.nsf.gov
NSF science and technical information

gopher://gopher.ngdc.noaa.gov
NOAA Geophysical Data Center
gopher://gcdis_gopher.esdim.noaa.gov
Global Change Data server

NASA

http://hypatia.gsfc.nasa.gov/NASA_homepage.html
The NASA Home Page
http://techreports.larc.nasa.gov/cgi-bin/NTRS
NASA Technical Report Server (NTRS)
http://cass.jsc.nasa.gov/jove/aboutjove.html
NASA University JOint VEnture (JOVE)
http://netgopher.lerc.nasa.gov/NASA_Select/NASA_Select.html
NASA Television on CU-SeeMe
http://www.jsc.nasa.gov/nasa/NASAInternet.html
NASA Internet Connections
http://amc.gsfc.nasa.gov/gcdc/gcdc.html
Global Change Data Center
http://spso2.gsfc.nasa.gov/spso_homepage.html
NASA Earth Observing System Project Science Office
http://images.jsc.nasa.gov/html/earth.htm
Earth Observation Images - NASA JSC
http://www.jpl.nasa.gov/jplnews.html
Recent news from JPL
http://www.gsfc.nasa.gov/hqpao/newsroom.html
The NASA Newsroom
http://cesdis.gsfc.nasa.gov/hpccm/hpcc.nasa.html
NASA HQ HPCC HomePage
http://www.jpl.nasa.gov/educ/education.html
JPL Educational Outreach
http://sdcd.gsfc.nasa.gov/ESS/
HPCC Earth and Space Science Applications Project
http://www.lerc.nasa.gov/Other_Groups/K-12/K-12_homepage.html
HPCC K-12 Home Page
http://seazar.jpl.nasa.gov/Edudoc.html
Education Resources - JPL
http://images.jsc.nasa.gov/html/earth.htm
Earth Observation Images
http://www.jpl.nasa.gov/jplnews.html
Recent news from JPL
http://www-library.gsfc.nasa.gov/
GSFC Library
http://spso2.gsfc.nasa.gov/spso_homepage.html
EOS Project Science Office
http://camille.gsfc.nasa.gov/rsd/
Public use of Remote Sensing Data- NASA CAN Projects
http://topex-www.jpl.nasa.gov/
Topex-Poseidon Home Page
http://seazar.jpl.nasa.gov/
JPL Physical Oceanography .DAAC Home Page

http://newproducts.jpl.nasa.gov/calendar/calendar.html
Space Calendar
gopher://info.latech.edu/11/FAQ/Space and NASA FAQ
Space and NASA Frequently Asked Questions
http://spacelink.msfc.nasa.gov/
NASA Spacelink
http://pepe.hitc.com/
NASA EOSDIS Core System/Flight Ops
http://southport.jpl.nasa.gov/
NASA/JPL Imaging Radar Homepage
http://www.gsfc.nasa.gov/hqpao/hqpao_home.html
NASA Public Affairs
http://wwwdaac.msfc.nasa.gov/wetnet.html
The WetNet Project
http://www.gsfc.nasa.gov/nasa_online_education.html
NASA On-line Education Resources
http://farside.gsfc.nasa.gov/ISTO/DLT/
Digital Library Technology
http://www.sti.nasa.gov/nasa-thesaurus.html
NASA Thesaurus
http://edhs1.gsfc.nasa.gov
The EOS Core System Data Handling System
http://guinan.gsfc.nasa.gov/K12/StarChild.html
The StarChild Project: Connecting NASA and K12
http://nctn.oact.hq.nasa.gov/nctnHome.html
NASA Commercial Technology
http://images.jsc.nasa.gov/html/pao.htm
NASA press release photos
http://pathfinder.arc.nasa.gov/
EOS Pathfinder Datasets
gopher://gopher.gsfc.nasa.gov
GSFC gopher server
ftp://pubinfo.jpl.nasa.gov
JPL public info/images
ftp://hpccpo.aero.hq.nasa.gov
High Performance Computing Program

Libraries

http://www.carl.org/carl.html
CARL Corporation - Network of libraries and databases
http://fas-www.harvard.edu/libraries/cabot/cabot.html
Cabot Science Library
http://www-library.gsfc.nasa.gov/
GSFC Library Front door
http://www-lj.eb.com/survey/beta.html
Encyclopedia Britannica Online Beta Program
http://tecfa.unige.ch/info-edu-comp.html
The World-Wide Web Virtual Library: Educ. Technology
http://lcweb.loc.gov/homepage/lchp.html
Library of Congress

Museums

http://sln.fi.edu/
The Franklin Institute Virtual Science Museum
http://www.exploratorium.edu/
Exploratorium Home Page

Discipline-specific

http://terrassa.pnl.gov:2080/EESC/resourcelist/hydrology.html
Hydrology-Related Internet Resources
http://www.eia.brad.ac.uk/btl/
Earth and Universe - UK Astronomy
http://muse.bio.cornell.edu/
Biodiversity and Biological Collections WWW Server
http://baervan.nmt.edu/
Gas and Oil Technology - New Mexico
http://www.geo.mtu.edu/eos/acronyms.html
EOS Acronyms/Volcanolgy Team
http://www2.waikato.ac.nz/c14/
U of Waikato, NZ Radiocarbon Dating Lab
gopher://dillon.geo.ep.utexas.edu
U of Texas GeoGopher

Career Opportunities

http://www.aip.org/aip/careers/careers.html
AIP PHYSICS CAREERS BULLETIN BOARD

Info Highway Projects and Demonstrations

http://www.nero.net/
NERO Project - Desktop Collaboration
http://vision.uchicago.edu/cgi-bin/labcam
Animate Agent LabCam (tm)
gopher://riceinfo.rice.edu:1170/11/Projects/Simulations
Shuttle Simulation Project
http://rsd.gsfc.nasa.gov/rsd/
Public use of Remote Sensing Data- NASA CAN Projects
http://www.covis.nwu.edu/
Collaborative Visualization Project, Northwestern Univ
http://farside.gsfc.nasa.gov/ISTO/DLT/
Digital Library Technology
ftp://hpccpo.aero.hq.nasa.gov
High Performance Computing Program

Institutions

http://www.usra.edu/
Universities Space Research Association
http://www.gfz-potsdam.de/welcome_eng.html
GeoForschungsZentrum Potsdam, Germany
http://ftp.clearlake.ibm.com/ERC/HomePage.html
Environmental Resource Center Home Page
http://www.phyast.pitt.edu/
Physics and astronomy, Univ of Pittsburg
http://www.ciesin.org/
Information for a Changing World - CIESIN
http://agcwww.bio.ns.ca/index.html
Atlantic Geoscience Centre Home Page
http://rainbow.ldeo.columbia.edu/
LDEO Climate Group Home Page
http://terrassa.pnl.gov:2080/
Batelle Pacific NW Welcome Page - Earth and Env Sci Center
http://www.ciesin.org/kiosk/home.html
CIESIN Information Kiosk
http://www-erl.mit.edu/
MIT Earth Resources Laboratory
http://www2.waikato.ac.nz/c14/
U of Waikato, NZ Radiocarbon Dating Lab
http://www.erim.org/
The Environmental Research Institute of Michigan
http://infoserver.ciesin.org:8080/ciesin-home.html
CIESIN Information Server
gopher://gopher.ciesin.org
CIESIN global change info

Maps

http://www.lib.utexas.edu/Libs/PCL/Map_collection/Map_collection.html
The Perry-Castañeda Library Map Collection
http://ellesmere.ccm.emr.ca/
National Atlas Information Service

Shared Resources

http://crnvmc.cern.ch/FIND/DICTIONARY?
English language Dictionary
http://www.sti.nasa.gov/nasa-thesaurus.html
NASA Thesaurus
telnet://fedix.fie.com login: follow instructions
Federal information exchange
gopher://barbarian.rs.itd.umich.edu 7777
X.500 Gateway Search
ftp://archive.afit.af.mil
NASA 2 Line Element Sets

USRA

Universities Space Research Association
Earth System Science Education Program

ESSE Universities

gopher://info.psu.edu:70/1
Penn State Gopher
http://www.geo.arizona.edu/
University of Arizona Geosciences
http://spacsun.rice.edu/
Space Physics and Astronomy at Rice University
http://space.rice.edu/hmns/connect.html
"Connection" Project, Rice Univ.
http://www.crseo.ucsb.edu/esrg.html
UCSB Earth Space Research Group Gateway
http://pangea.stanford.edu/ESYS.html
Earth System Science at Stanford
http://h2o.seagrant.wisc.edu/home.html
UW Sea Grant Home Page
http://www.gsfc.nasa.gov/nasa_online_education.html
NASA Online Educational Resources
http://www.uiowa.edu/
The University of Iowa Home Page
http://zephyr.rice.edu/department/dept_intro.html
Rice University Department of Geology and Geophysics
http://www.mps.ohio-state.edu/
Byrd Polar Research Home Page
http://www.cgrer.uiowa.edu/
Center for Global and Regional Environmental Research, UIowa
http://pangea.stanford.edu/EarthSci.html
Stanford Earth Sciences

NASA - Earth Observing System

This section compiled by Bill North <north@spso.gsfc.nasa.gov>

Programmatic Information:

http://www.mtpe.hq.nasa.gov/HQ_MTPE_homepage.html
Mission to Planet Earth:
http://gcmd.gsfc.nasa.gov/
GCMD - Global Change Master Directory:
http://spso.gsfc.nasa.gov/spso_homepage.html
EOS Project Science Office:
http://harp.gsfc.nasa.gov:1729/eosdis_documents/eosdis_hme.html
Version 0 System IMS:
http://eos.nasa.gov
ESDIS Working Document Archive:
http://edhs1.gsfc.nasa.gov
EDHS - ECS Data Handling System

DAACs - Distributed Active Archive Centers

http://eosims.asf.alaska.edu:12355
Alaska SAR Facility DAAC
http://sun1.cr.usgs.gov/landdaac/landdaac.html
EROS Data Center DAAC
http://daac.gsfc.nasa.gov
Goddard DAAC
http://seazar.jpl.nasa.gov
JPL DAAC
http://eosdis.larc.nasa.gov
Langley DAAC
http://wwwdaac.msfc.nasa.gov
Marshall DAAC
http://eosims.colorado.edu:1733
National Snow andIce DataCenter DAAC
http://www-eosdis.ornl.gov
Oak Ridge National Laboratory DAAC
http://www.ciesin.org
Socio Economic Data Archive Center DAAC:

Other Earth Data Centers:

http://www.ucar.edu/dss/index.html
NCAR Data Archive
http://www.ucar.edu/dss/datasets.html#avail
Datasets at NCAR
http://www.ncdc.noaa.gov/ncdc.html
NCDC - National Climatic Data Center
http://www.esdim.noaa.gov/
NOAA ESDIM
http://www.ngdc.noaa.gov/ngdc.html
NOAA NGDC - National Geophysical Data Center

http://www.nodc.noaa.gov/
NOAA NODC - National Oceanographic Data Center
http://nss.noaa.gov/saa/homepage.html
NOAA SAA - Satellite Active Archive
http://nssdc.gsfc.nasa.gov/cd-rom/cd-rom.html
NSSDC CD-ROM Catalog:

Instruments:

http://haleakala.jpl.nasa.gov/asterhome.html
Aster
http://spocls.larc.nasa.gov/ceres/cereshome.html
CERES - Clouds and the Earth's Radiant Energy System
http://climate.gsfc.nasa.gov/~gumley/Home.html
MODIS Airborne Simulator
http://eos.acd.ucar.edu/mopitt/home.html
MOPITT
http://seawifs.gsfc.nasa.gov
SeaWiFS

Earth Data & Imagery:

http://xtreme.gsfc.nasa.gov
AVHRR Land Pathfinder
http://192.134.216.41
AVISO TOPEX/Poseidon data
http://podaac-www.jpl.nasa.gov/topex
JPL TOPEX/POSEIDON Images
http://southport.jpl.nasa.gov
NASA/JPL Imaging Radar Homepage
http://sst-www.jpl.nasa.gov
Oceans SST Pathfinder (NOAA/NASA)
http://www.jpl.nasa.gov/sircxsar.html
SIR-C/XsSAR images
http://www.mth.uea.ac.uk/ocean/oceanography.html
The World-Wide Web Library: Oceanography

Interdisciplinary Studies:

http://www.geo.mtu.edu/eos/
A Global Assessment of Active Volcanism ...
http://www.coare.ucar.edu/TCIPOhome.html
TOGA COARE Information Services
http://thunder.atms.purdue.edu:80/toga_atlas
Climatology for TOGA-COARE and Adjacent Regions
http://www.pmel.noaa.gov/toga-tao/home.html
TOGA-TAO
http://www.pmel.noaa.gov/toga-tao/realtime.html
Realtime TOGA-TAO Buoy Data Access

Data Formats & Structures:

http://www.ncsa.uiuc.edu/General/NCSAHome.html
National Center for Supercomputing Applications
http://hdf.ncsa.uiuc.edu:8001
HDF information server
http://fits.cv.nrao.edu/traffic/scidataformats/faq.html
Scientific Data Format Information FAQ
http://sslab.colorado.edu:2222/ssl_homepage.html
Software Support Laboratory (NASA)

Other Sites:

http://sparc1k.images.alaska.edu
ASF Science
http://www.aodc.gov.au/AODC.html
Australian Oceanographic Data Centre (AODC)
http://www-ccs.ucsd.edu/
Center for Coastal Studies, SIO, UCSD
http://www-ccs.ucsd.edu/ccs/about_datazoo.html
The Data Zoo at CCS
http://milkman.cac.psu.edu/~reh113/index.html
Decoded Offshore Weather Data
http://iabp.apl.washington.edu
International Arctic Buoy Program (IABP)
http://rainbow.ldgo.columbia.edu/
LDEA Climate Group
http://ferret.wrc.noaa.gov/ferret/main-menu.html
Live Access to Climate Databases
http://www.jpl.nasa.gov
NASA Jet Propulsion Laboratory
http://www.ucar.edu/metapage.html
NCAR
http://nemo.ucsd.edu/nemo_front.html
NEMO - Oceanographic Data Server (SIO)
http://www.noaa.gov/
NOAA
http://www.cms.udel.edu
Ocean Info Center (OCEANIC) at U of Delaware
http://columbia.wrc.noaa.gov/pmelhome.html
Pacific Marine Environmental Laboratory (PMEL)
http://sio.ucsd.edu
Scripps Institution of Oceanography
http://www.soest.hawaii.edu
U of Hawaii School of Ocean & Earth Sci & Tech
http://bramble.er.usgs.gov
USGS Atlantic Marine Geology
http://geochange.er.usgs.gov/gch.html
USGS Global Change Research Program
http://diu.cms.udel.edu/woce/oceanic.html
WOCE Data Information Unit
http://www.whoi.edu/
Woods Hole Oceanographic Institution

References cited

BESS National Advisory Committee (1994). *The Biological and Earth Systems Science Curriculum. Report to the Worthington Board of Education*. Columbus, OH: The Ohio State University Research Foundation.

Brown, A.L. & J.C. Campione, (1994). Guided discovered in a community of learners. In: K. McGilly (ed.) *Classroom lessons: Integrating cognitive theory and classroom practice.* Cambridge, MA: MIT Press/Bradford Books, 229-270.

Earth Systems Science Committee, (1988). *Earth System Science. A Closer View.* Washington, DC: NASA

Fortner, R.W. (1989). Down to Earth Biology: A planetary perspective for the biology curriculum. *American Biology Teacher* 54 (2): 76-79. February.

Fullan, M. (1991). *The Meaning of Educational Change.* New York: Teachers College Press.

Mayer, V.J. (1991) Earth-system science: A planetary perspective. *The Science Teacher* 58 (1), 31-36.

Mayer, V.J. & Armstrong, R.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.

Mayer, et al . (1992). The role of Planet Earth in the new science curriculum. *Journal of Geological Education* 40:66-73.

Mayer, V.J., Fortner, R.W. & Hoyt, W.L. (1995). *Science is a study of Earth. A resource guide for science curriculum restructure.* Columbus, OH: The Ohio State University Research Foundation.

Mayer, V.J., Fortner, R.W. & Hoyt, W.L. (in review) Using cooperative learning as a structure for Earth Systems Education workshops. *Journal of Geological Education.*

National Science Teachers Association. (1992). *Scope, Sequence, Coordination .The Content Core: A Guide for Curriculum Designers.* Washington, DC: Author.

National Committee on Science Education Standards and Assessment. (November 1994 Draft). *National Science Education Standards.* Washington, DC: National Academy Press.

Rutherford, F.J. & Ahlgren, A. (1989). *Science for All Americans.* New York: Oxford University Press.

Secretary's Commission on Achieving Necessary Skills (1992). *Learning a Living: A blueprint for high performance.* Washington, DC: US Department of Labor.

APPENDIX

- Agenda for High School Symposium
- Participant List
- Exploring Earth Systems Education
  (Key articles about ESE philosophy)
- Earth Systems Education Bibliography

Participant list of the ESE Symposium for High School Science

First Name	Last Name	Affiliation	Street	City/State	Zip	Work Phone
Damon	Asbury	Worthington Schools	752 High St.	Worthington, OH	43085	614/431-6500
John	Austin	Hays High School	104 Oak Hill Ave.	Delaware, OH	43015	614/369-7656
Constance	Barsky	Project Discovery	4138 Smith Laboratories 174 West 18th Ave.	Columbus, OH	43210	614/292-3323
Dan	Bertsch	Cuyahoga Valley EE Center	3675 Oakhill Rd.	Peninsula, OH	44624	216/657-2796
Chuck	Borland	Bozeman High School	404 West Main	Bozeman, MT	59715	406/585-1820 Ext. 1604
Al	Capotosto	Maple Newtown High School	120 Media Line Rd.	Newtown Square, PA	19073	610/359-4237 Ext. 4226
Rene'	Carson	Little Rock School District Instructional Resource Center	600 S. Ringo	Little Rock, AR	72201	501/324-0518
Marsha	Cavanaugh	Thomas Worthington H. S.	300 W. Granville Rd.	Worthington, OH	43085	614/431-6565
Jerry	Cooper	Bozeman High School	404 West Main	Bozeman, MT	59715	406/585-1650
Carolyn	Dawson	UNC Tointon Institute	1216 27th St.	Greeley, CO	80631	303/351-2101
Dee	Drake	Huron High School	2727 Fuller Rd.	Ann Arbor, MI	48105	313/994-2083
Joan	Dutt	SD NSF-SSI	2510 E. Franklin	Pierre, SD	57501	605/773-6400
Arvon	Engel	University of Northern Colorado	College of Education Laboratory School	Greeley, CO	80639	303/351-2321
Rosanne	Fortner	Ohio Sea Grant Education	29 W. Woodruff Ave.	Columbus, OH	43210	614/292-1078
Cindy	Fushimi	Worthington Kilbourne H.S.	1499 Hard Rd.	Worthington, OH	43235	614/431-6226
Brian	Geniusz	Thomas Worthington H.S.	6517 Millridge Circle	Dublin, OH	43017	614/431-6565

First Name	Last Name	Affiliation	Street	City/State	Zip	Work Phone
Kelly	Gatewood	Omaha North H.S.	4410 N. 36th St.	Omaha, NE	68111	402/557-3400
Richard	Hastings	Wiggins H.S.	Dept. of Earth Science	Greeley, CO	80631	303/351-2598
Jewel	Ho	Keelung Girls' H.S.	324 Tung-Shin Rd.	Taiwan ROC		02-4321680
Joaquin	Jordan	Columbus City Schools	2988 W. Case Rd.	Dublin, OH	43017	614/766-9699
Janet	Kahan	Ann Arbor Schools	2725 Boardwalk	Ann Arbor, MI	48106	313/994-2162
Michael	Kalb	USRA	7501 Forbes Blvd. Ste 206	Seabrook, MD	20706	301/805-8396
David	Kibler	Roy C. Ketcham High School	99 Myers Corners Rd.	Wappingers Fall, NY	12590	914/248-5100
Karen	Kochheiser	Thomas Worthington H. S.	300 W. Granville Rd.	Worthington, OH	43085	614/431-6565 Ext. 1059
Craig	Kramer	Bexley High School	326 S. Cassingham Rd.	Bexley, OH	43209	614/231-4591
William	Lawrence	Concord Academy	166 Main St.	Concord, MA	01742	508/369-6080
Al	Lewandowski	Ohio Sea Grant Education	6275 Burns Line Rd.	Croswell, MI	48422	614/292-1078
Gloria	Letts	Columbus City Schools	873 Walcutt Ave.	Columbus, OH	43219	614/365-5297
Lana	Lowary	Olentangy Local Schools	259 Highburn	Gahanna, OH	43230	614/548-5800
Brian	Luthy	Thomas Worthington H. S.	300 W. Granville Rd.	Worthington, OH	43085	614/431-6565
Farzad	Mahootian	Gonzaga Colege High School	19 Eye St. NW	Washington, D.C.	20001	202/336-717
Mark	Maley	Thomas Worthington H.S.	300 W. Granville Rd.	Worthington , OH	43085	614/431-6565
Victor	Mayer	Ohio Sea Grant Education	29 W. Woodruff Ave.	Columbus, OH	43210	614/292-1078
Heidi	Miller	Earth Systems Education	2086 Iuka Ave.	Columbus, OH	43201	614/292-1078
Donna	Millett	Attleboro High School	Rathburn Willard Dr.	Attleboro, MA	02703	508/222-5150 Ext.252

First Name	Last Name	Affiliation	Street	City/State	Zip	Work Phone
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Tony	Murphy	GLOBE	744 Jackson Place	Washington, DC	20503	202/395-7600
Robert	Myers	Classroom of The Future Wheeling Jesuit College	316 Washington Ave.	Wheeling, WV	26003	304/243-238
John	Oliver	Willsboro Central School		Willsboro, NY	12996	
Mary Ann	Patten	Marceline R-V School	314 E. Sante Fe	Marceline, MO	64658	816/376-2411
O. H.	Patten	Marceline R.V. School	314 E. Sante Fe	Marceline, MO	64658	816/376-2411
Ron	Pilatowski	Thomas Worthington H. S.	300 W. Granville Rd.	Worthington, OH	43085	614/431-6565
Harold	Pratt	National Research Council Science Education Standards	2101 Constitution Ave. HA 486	Washington, DC	20418	202/334-1399
Howard	Rein	Bozeman High School	404 West Main	Bozeman, MT	59715	406/585-1650
Robert	Ridky	University of Maryland	4312 Knox Rd.	College Park, MD	20742	301/405-4090
Joe	Riley	Ballas #2	2725 Boardwalk	Ann Arbor, MI	48106	313/994-2162
Barry	Rock	The GLOBE Program	744 Jackson Place	Washington, DC	20503	202/395-7600
Paul	Rockman	Kean College		Union, NJ	07083	908/527-2894
Donny	Roush	Ohio Sea Grant Education	1511 Ashland Ave.	Columbus, OH	43212	614/292-1078
Lyn	Samp	Dedham H.S.	51 Whiting Ave.	Dedham, MA	02094	617/326-6900
Jeffrey	Samson	Gateway Regional High Schooi	Littleville Rd.	Huntington, MA	01050	413/667-8711
Ed	Shay	Worthington Schools (retired)	P. O. Box 496	Langley, WA	98260	
Jerry	Sherman	Millbrook High School	P. O. Box AA	Millbrook, NY	12545	914/677-4210
Sonal	Sheth	Thomas Worthington H.S.	300 W. Granville Rd.	Worthington, OH	43085	614/431-6565

First Name	Last Name	Affiliation	Street	City/State	Zip	Work Phone
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Raymond	Tschillard	UNC Tointon Institute	Laboratory School	Greeley, CO	80639	303/351-2291
Frank	Tuttle	Dublin High School	6780 Coffman Rd.	Dublin, OH	43017	614/764-5900
Daniel	Wagner	UNC Tointon Institute	Laboratory School	Greeley, CO	80639	303/351-2196
Leslie	Walter	Pioneer High School	601 W. Stadium	Ann Arbor, MI	48103	313/994-2120
Daniel	Warner	UNC Tointon Institute	Laboratory School	Greeley, CO	80639	303/351-2321
Gardner	Watkins	Dublin High School	6780 Coffman Rd.	Dublin, OH	43017	614/764-5900
John	Yoder	North Salem High School	765 14th St. NE	Salem, OR	97301	503/399-3241

Earth Systems Education
High School Symposium

October 13-16, 1994

Thursday	8 PM	Participants arrive; reception at Parke Hotel	
	8:30	Welcome and Introduction; College of Education and School of Natural Resources	
	8:45	Meeting National Standards with an Earth Systems approach	Harold Pratt, National Research Coun.
Friday	8 AM	Continental breakfast	
(Hotel)	8:30	Symposium introduction	Rosanne Fortner Victor Mayer
		ESE: a teacher's view	Ed Shay
	9:15	Earth Systems Science: Curriculum Restructure, all levels	USRA, ODE
	9:45	Break	
	10:00	Participant presentations: ESE Infusion Unit examples	
	11:30	Breakout sessions: Discussion	
		Lunch at Parke Hotel for invited participants	
	1 PM	BESS overview: District level restructure of HS science	BESS tchrs
	2:45	Break	
	3:00	Participant presentations: ESE courses and district changes Group Discussion (continues through dinner at the hotel)	
	6:00	Buffet Dinner for invited participants	
	7:00	Refreshments and Exhibits, Kottman Hall lobby	
	8:00	Open Lecture, 103 Kottman: GLOBE program	Barry Rock, GLOBE Sci. Director
Saturday	AM	Displays in Kottman Hall	
	9:00	Concurrent Sessions; Arts and history in teaching science PLESE participants, discussion of new proposals	Victor Mayer Rosanne Fortner
	9:45	Break	
	10:00	Science panel: Advances in Understanding Global Change	OSU Scientists
		Lunch and PM sessions at National Center for Science Teaching and Learning	Invited Participants
	1 PM	Introduction of Earth Systems Education Resource Guide	Victor Mayer
	1:30	Group sessions: restructure hurdles and how-to's	
	2:30	Break	
	2:45	Technology sessions, hands on and demo, rooms B&C JEI demonstration, others	Al Lewandowski, Robert Ridky,
	5:00	Adjourn	Al Capotosto
	6:00	Resource Center closes	
		Dinner on the town	
Sunday	9 AM	Continental breakfast at hotel	
	9:30	Opportunities in Earth Systems Education	AGI, Networks, etc.
	10:30	HS science restructure: future directions and support Group discussions	
	Noon	Adjourn	

Exploring Earth Systems Education

In this first section we have included a series of published articles which the reader can use to develop a background knowledge of the philosophy and history behind Earth Systems Education (ESE). All have been written by individuals involved throughout the development of ESE efforts. Together they represent a history of the development of ESE and an insight into the fundamental philosophy of the program.

Overview of Articles

The Role of Planet Earth in the New Science Curriculum

This article appeared in the *Journal of Geological Education* and is a record of the emergence of ESE from a concern for more effective teaching about the Earth. It was directed at the Earth Science Education community which represents a well established curriculum interest group here in the United States, unique in the world. The article therefore focuses on the problems of Earth science education as an under represented force in science curriculum decision making and curriculum reform. It is the first published source which suggests that planet Earth might be the logical focus and organizing principle behind a truly integrated science curriculum. As such, it provides a rationale for such a focus. It cites some support for this idea from the writing of Stephen Gould.

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

The second article is the report of a 1988 conference in which the first suggestions for an Earth Systems Education approach to science curriculum and teaching were made. This conference, held to supplement the efforts of Project 2061 of the American Association for the Advancement of Science, included scientists from various federal science agencies and universities, and teachers and science educators from many areas of the United States. Several of the teachers in this conference went on to become essential contributors to the philosophy and structure of Earth Systems Education. The seven Earth Systems Understandings (see the ESE Framework at the end of this section) evolved out of the ten concepts that the conferees concluded were essential components of any science education reform movement. The article, originally published in the journal *Science Education*, will provide the reader with an understanding of the national context in which the ESE concept was formulated and prospered. It also demonstrates the solid, scientific, and practical educational underpinnings of ESE.

The Essential Contributions of Earth Science to Science

There are several contributions of the Earth sciences to science that normally go unnoticed and unrepresented in the science curriculum. Two articles provide a discussion of the three types of contributions; philosophical, methodological, and conceptual. The first article, "Earth–systems science: A planetary perspective" from *The Science Teacher* provides a general overview for practicing teachers of these contributions. It makes a strong case for their inclusion in all science curricula. The second article, "Down to Earth biology", was published in the *American Biology Teacher*. It applies the Earth science contributions in the three domains to secondary school biology courses. It suggests ways in which these unique contributions, such as Deep Time, can be used to enhance biology students' understanding of the Earth they live upon.

Reprinted from *Science is a Study of Earth: A Resource Guide for Science Curriculum Restructure.* Columbus: Earth Systems Education Program, 1995.

EARTH APPRECIATION

This article appeared in *The Science Teacher*. It provides a powerful argument for the inclusion of aesthetic components in science courses. The Earth is beautiful. Its beauty needs to be preserved for future populations to enjoy as our students do. Therefore we must understand its processes and how we influence those processes with population growth and the growth of technology. The article provides examples of how teachers can provide instruction that enhances ESE Understanding #1 (The Earth is unique, a planet of rare beauty and great value) among their students.

CONCLUSION OF SECTION

This first section of the Resource Guide concludes with two "fact sheets" that can be used by teachers in providing background to parents, school administrators and other teachers of Earth Systems Education and an annotated bibliography of the articles that have been written about this unique science curriculum effort. The first fact sheet is an issue of the ERIC/CSMEE Digest titled **Earth Systems Education.** It provides a brief summary of the development and nature of Earth Systems Education. Following the issue of the Digest, is the most recent version of the **Framework for Earth Systems Education.** It provides the conceptual "check list" for the development of science curriculum.

AN ANNOTATED BIBLIOGRAPHY OF EARTH SYSTEMS EDUCATION ARTICLES

There are other articles that have been published about ESE. You might be interested in doing some further reading. If so, we provide here an annotated list of all such articles published at the time this Resource Guide was completed.

Fortner, R.W. (ed.). 1991. Special Earth Systems Education issue of *Science Activities*. Spring: 28:1.

This issue of *Science Activities* includes the Earth Systems Education Framework and articles with suggestions for teaching toward each of the seven Understandings of the framework. It has won a special journal editors award for excellence.

Fortner, Rosanne W., et al. 1992. Biological and Earth Systems Science. *The Science Teacher* 59(9):32-37.

A description of the Worthington, Ohio, Biological and Earth Systems Science (BESS) course sequence. This is a two-year integrated course at the high school level, replacing the traditional Earth Science and Biology courses for all students.

Fortner, Rosanne W. 1992. Down to Earth biology. *The American Biology Teacher* 54(2):76-79.

A description of the general concepts from the Earth Sciences which, if taught in biology courses, would provide a stronger context and background of biology concepts for high school biology students.

Fortner, Rosanne W. 1991. A Place for EE in the Restructured Science Curriculum. In, Baldwin, J.H. (ed.), *Confronting Environmental Challenges in a Changing World* Troy, OH: North American Association for Environmental Education.

A description of the environmental education goals that can be met by using an Earth Systems focus for the restructuring of the science curriculum.

Mayer, V.J. 1989. Earth appreciation. *The Science Teacher* 56(3)::60-63.

A discussion regarding the place of aesthetics in teaching about planet Earth. Examples are drawn from art, history, and literature that illustrate their use in teaching science.

Mayer, V.J. 1990. Teaching from a global point of view. *The Science Teacher* 57(1)::47-51.

A description of how science can be used as a model for global education. Suggestions are provided as to how science teachers can incorporate global education into their classes.

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

Summary of the 1988 conference involving scientists from NASA, NOAA, USGS, and several universities, and science teachers and administrators to determine what every citizen should

understand about planet Earth in order to live "responsible and productive lives in our democracy."

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

An examination of the philosophical, methodological, and conceptual contributions the study of the Earth sciences can make to the K–12 curriculum.

Mayer, V.J., et al. 1992. The Role of Planet Earth in the New Science Curriculum. *Journal of Geological Education* 40:66-73.

This is a description of the rationale for the use of Earth as a focus for the integration of science programs, K–12. It is directed at the Earth science educational community and therefore documents the frustrations of that community with the general failure to include significant content from the Earth sciences into K–12 curricula, especially at the senior high school level.

Mayer, V.J. 1993. The future of the Geosciences in the Pre–College Curriculum. Paper presented at the International Conference on Geoscience Education and Training (Southampton, England, United Kingdom, April 23, 1993). ED 368 556.

This is an update of the earlier article which appeared in the *Journal of Geological Education*. It provides a much stronger argument for the development of integrated science curricula using Earth as the organizing focus. A version of this ERIC document will be published as an article in *Science Education*.

EARTH SYSTEMS EDUCATION BIBLIOGRAPHY

This is an annotated listing of books and articles that have been found to be useful in Earth Systems Education, especially in reorienting one's thinking from traditional science to a more modern perspective of the content and methodology of the science for future American needs. The books described are ones that individuals on the PLESE staff have read and found to be of interest to them. The listing is by no means exhaustive. It is heavily weighted toward literature, art, and history. The teacher will find many useful examples and images to use in classroom instruction in these books.

ACCURATE, POPULAR WRITINGS

John McPhee. New York: Farrar, Straus, Giroux.
The Control of Nature. 1989. Stories about our attempts to control nature. They include volcanic eruptions in Iceland and Hawaii, the Mississippi River, and fires and landslides in the Los Angeles mountains.

Encounters with the Archdruid. 1971. McPhee describes encounters of David Brower, long-time executive secretary of the Sierra Club, Charles Park, an exploration geologist in Wyoming, Charles Fraser, developer of Hilton Head resort area, and Floyd Dominy who, as head of the Bureau of Reclamation, has been responsible for many water impoundment projects in the West.

In Suspect Terrain. 1982. Stories that relate the controversies surrounding the acceptance of the new theory of plate tectonics; the role of geologist, Anita Harris, in those controversies, and her contributions to an understanding of Appalachian geology.

Rising from the Plains. 1986. In telling the life story of John Love, geologist who worked out the history of Wyoming, McPhee provides a vivid description of the evolution of the western landscapes, as well as an insight into the frontier life that Love experienced as a child and young man.

Basin and Range. 1980. In describing the theory of plate tectonics through a discussion of various American landscapes, especially the province in the title, McPhee relates a narrative of the history of geology as well.

Assembling California. 1993. McPhee follows his pattern of telling both the story of the professional life of a geologist and the development of the terrain the geologist studied during his career. In this case it is Eldridge Moores from the University of California. He contributed greatly to a new understanding of California as an assemblage of separate pieces of country drifting across the ocean basin to form the state.

Mark Reisner. New York: Penguin Books. ***Cadillac Desert.*** 1986.
Riesner has written a provacative description of the efforts of western landowners and politicians to establish a water policy that has provided short-term profits to individuals, but is resulting in long-term destruction of the environment and significant cost to the taxpayers of the rest of the nation.

PUBLICATIONS BY LITERATE SCIENTISTS

Nigel Calder. New York: Viking Press.
Timescale: An Atlas of the Fourth Dimension. 1983. This is a richly illustrated documentation of the history of our Earth and its environment in space.

Niles Eldredge. New York: Simon and Schuster, Inc.
Time Frames: The Rethinking of Darwinian Evolution and the Theory of Punctuated Equilibrium. 1985.
A fascinating account of how a careful and meticulous study of the fossil record led Eldredge and Stephen Gould to propose their revolutionary theory of Punctuated Equilibrium.

Stephen Jay Gould. New York: W.W. Norton and Co.
The Panda's Thumb. 1980; ***Hen's Teeth and Horse's Toes.*** 1983; ***The Flamingo's Smile.*** 1985; ***An Urchin in the Storm.*** 1987; ***Bully for Brontosaurus.*** 1992. This is a series of books that include monthly columns published in ***Natural History Magazine.*** They range widely in topics, but most center on evolution and/or the nature of science.

Wonderful Life. 1989. A discussion of the implications of the Burgess Shale fauna for our understanding of the nature of evolution. Entertaining and informative reading on the nature of science, scientific investigation, and theory development.

John Wesley Powell. Chicago: The University of Chicago Press. ***The Exploration of the Colorado River.*** 1957.
Excerpts from Powell's journal of his exploration of the river include observations of the Grand Canyon and the Colorado River that can be used to teach basic concepts of erosion, sedimentation, and geological history. He was an excellent writer and one who was able to impart the excitement of scientific exploration and discovery. A newer version entitled, ***Down The Colorado,*** published in 1988 by Arrowood Press, New York, includes spectacular color photography by Eliot Porter.

Novels and the Earth System

Michael Critchton. New York: Alfred A. Knopf. ***Jurassic Park.*** 1990.
The author weaves modern developments in genetic engineering, paleontology, and chaos theory into a chilling tale which questions our reductionist, deterministic bent in science. The story evolves around the recreation of dinosaurs from DNA fragments found in fossils with the idea of creating the ultimate amusement part. As you might expect, things go terribly wrong.

Allen Eckert. Boston, MA: Little, Brown and Co. ***The Frontiersman.*** 1967.
Includes the story of Tecumseh and his use of comets, boloids, and the New Madrid earthquake in attempting to rally Indian tribes to battle the Americans. Has an excellent description of the great earthquake.

James A. Michener. New York: Random House. ***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 geologist to interpret the history of an area.

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.

Hawaii. 1959. He describes the evolution of the Hawaiian islands in very vivid prose, providing insight into the volcanic processes that formed and continue to mold the islands.

Edward Rutherford. New York: Ivy Books. ***Sarum.*** 1987.
The fictionalized story of the history of Salisbury, England. The first chapter starts the narrative during the last (Wisconsin) ice age and tells of the migration of the prehistoric inhabitants of the European continent, and how some got to what is now (post glaciation) the island of England.

Jane Smiley. New York: Ivy Books. ***The Greenlanders.*** 1988.
The fictionalized story of the settlement of Greenland by Icelanders and the story of their struggle in an increasingly harsher environment.

Irving Stone. New York: New American Library. **The Origin.** 1980.
A biographical novel of the life of Charles Darwin.

The Physics Community and the Real World

Luis W. Alvarez. New York: Basic Books, Inc. **Alvarez: Adventures of a Physicist.** 1987.
The autobiography of a Nobel Laureate in physics who helped in the development of the atomic bomb and involved himself deeply in the politics of science. His last major contribution to science was the impact theory for the extinction of the dinosaurs, developed with his son, a professor of geology at the University of California, Berkeley.

James Gleick. New York: Penguin Books. *Chaos: Making a New Science*. 1987.
The physics community is now considering nature as a subject of inquiry. A dramatic revolution is now going on in the conversion from what has been called linear science, the tradition of physics, to nonlinear science, more representative of the "real world." The author describes in readable and interesting detail this revolution and the theory behind it.

Daniel J. Kelves. Cambridge: Harvard University Press. **The Physicists.** 1987.
Kelves documents the history of science in America, starting with pre-Civil War up to the height of the Cold War (the book was orignally published in 1971). He describes the rise of the physics community in its influence on national science policy as a result of its contributions during World War I, II, and the Cold War. In the process it eclipsed the Earth science community which had achieved leadership in American science policy during the expansion of the frontier and the search for natural resources.

Art and Earth Systems

Art and Geology is a fascinating book, published in 1986 by Gibbs M. Smith, Inc. of Layton, Utah, that relates an impressionistic painting to the geological scene that inspired it. Rita Deanin Abbey is the artist and G. William Fiero the geologist and photographer.

Georgia O'Keefe by Nancy Frazier, published by Crescent Books, New York, in 1990, includes a portfolio of the finest works of this unique artist. They include her distinctive symbolic representations of vegetation, southwest landscapes, and city scenes. The author also provides a brief biography of O'Keefe.

The American Vision: Landscape Paintings of the United States by Malcolm Robinson, published by Portland House, New York, in 1988, is an historical review of important landscape painters and includes over 80 full color reproductions of our most important paintings.

Turner and the Sublime by Andrew Winton, is published by The University of Chicago Press, Chicago, 1980. Turner subscribed to the aesthetic theory of the sublime where a simple view, or a landscape painting, would take the observer beyond the objective reality to lift up the soul, filling it with joy and exaltation. This book includes many of his landscapes painted in this tradition.

Albert Bierstadt: Painter of the American West by Gordon Hendricks, is published by Harrison House, New York, 1988. This biography includes most of the western landscapes developed on the artist's western trips, many in full color.

The Hudson River and its Painters by John K. Howat, is published by American Legacy Press, New York, 1983. This group of American artists with its sense of national pride and deep reverence for the beauty of the Hudson River Valley portrayed their subject's spectacular cliffs and chasms, jutting rocks, vine-covered banks, and swirling waters with great and often mysterious beauty.

Exceptional Earth Systems Photography

Ansel Adams' work can provide images for use in classes as a source of both technical information and aesthetically pleasing views.

Ansel Adams: Classic Images is published by Little, Brown and Company, Boston, 1985. Selected by Adams during the last years of his life, the images in this book include many of his most magnificent landscapes and photographs of some of the intimate details of nature.
The Mural Project, by Peter Wright and John Armor, is published by Reverie Press, Santa Barbara, CA, 1989. Adams was commissioned in the early 1940s by the U.S. Department of Interior to take a series of photographs in the western national parks. Started but never completed because of the Second World War, his completed photographs were first presented to the public in this volume. They are accompanied by excerpts from the wilderness writings and speeches of Theodore Roosevelt.

Eliot Porter was one of our most accomplished photographers of nature. His color plates of grand views and close-up details of nature can provide the classroom teacher with both technically useful and aesthetically pleasing images for classroom use.

Eliot Porter, American Places by Wallace Stegner and Page Stegner, is published by Greenwich House, New York, 1987. It is a photographic trek across the North American Continent.
Nature's Chaos by Eliot Porter and James Gleick, is published by Viking Penguin, New York, 1990. Scientists are beginning to discover the patterns, relationships, and interactions that are present in the disorder of nature. Porter has been fascinated by this apparent regularity among the disorder, and in this book brings together many images that seem to exemplify chaos theory within nature.
Eliot Porter with photographs and text by the author, is published by New York Graphic Society Books, 1987. At 85, the author has pulled together a personal reminiscence of a lifetime of discovery, adventure, and devotion to his art. The book includes popular classics and rare never-before published images.

American Astronaut Photography: The View from Space by Ron Schick and Julia Van Haaften, is published by Clarkson N. Potter, Inc., New York, 1988. Over 120 historic images from the golden age of space exploration, taken by the astronauts, are included in this volume.

MISCELLANEOUS LITERATURE

The Earth Speaks by Steve Van Matre and Bill Weiler, is published by The Institute for Earth Education, Warrenville, IL, 1983. Quotes from the writings of authors such as Thoreau, Muir, and Carson capture the voice of Earth as it speaks to its inhabitants of its beauty.

Keepers of the Earth by Michael J. Caduto and Joseph Bruchac, is published by Fulcrum, Inc., Golden, CO, 1988. This book is a collection of North American Indian stories with related hands-on activities designed to help readers feel a part of their surroundings.

A Far Side Collection: Unnatural Selections by Gary Larson, is published by Andrews and McMeel, Kansas City, 1991. This collection of his recent cartoons includes Larson's interpretation of the evolution of life on Earth in five double-page color panels.

Scientific Progress Goes "Boink" by Bill Watterson, is published by Andrew McMeel, Kansas City, 1991. This collection of the adventures of Calvin and Hobbes includes their photographic excursion to the Jurassic, and Calvin's trips to several planets.