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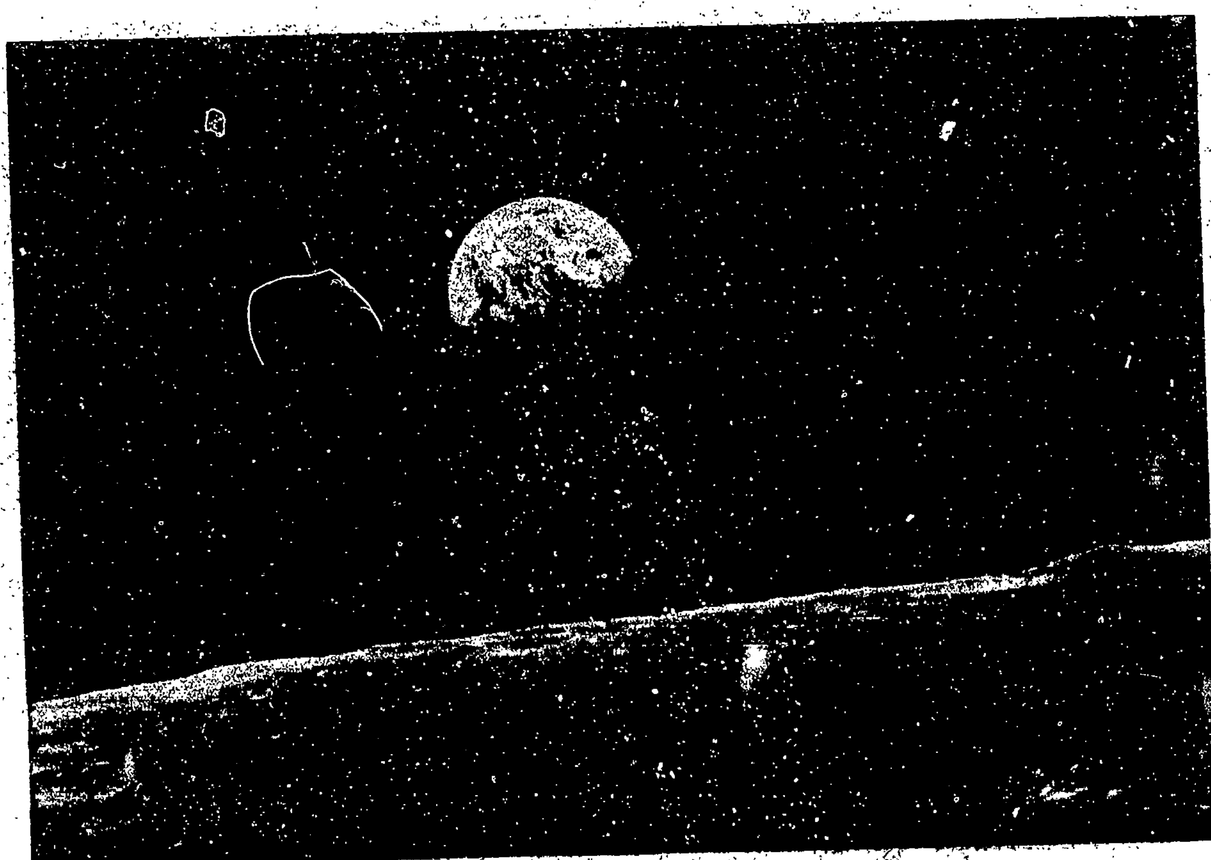
ABSTRACT

Biological and Earth Systems Science (BESS) is a two-year integrated biological and earth systems science curriculum for ninth and tenth grade students developed in response to the national and statewide dissatisfaction with secondary science programs. This report provides an overview of the program's history, aims, implementation strategies, evaluation procedures, and recommendations for program improvement. Also included in this document are: (1) a current draft outline of the National Science Standards of the National Research Council; (2) excerpts from the current draft of the Ohio Science Standards; (3) a speech entitled "Postmodern Science and the Responsible Citizen in a Knowledge-Intensive Era" by Paul DeHart Hurd; and (4) an article from The Science Teacher entitled "Biological and Earth Systems Science," which provides a closer look at the BESS program. (ZWH)

THE BIOLOGICAL AND EARTH SYSTEMS SCIENCE CURRICULUM

Report to the Worthington Board of Education



The BESS National Advisory Committee
and
The Ohio State University

THE BIOLOGICAL AND EARTH SYSTEMS SCIENCE CURRICULUM

Report to the Worthington Board of Education

Part I - Historical Setting

In 1990, the high school biology and earth science teachers of the Worthington School District implemented the two-year integrated biological and earth systems science curriculum for all ninth and tenth grade students in the district. This was in response to several factors within the district, including concern about the failure of nearly 50% of the student population to acquire fundamental background knowledge about the Earth and its several subsystems, including the atmosphere, hydrosphere, and lithosphere. Additional problems centered around the nature of the biology course as it was offered at the time. Much of the content seemed to be irrelevant to most students. Little was useful for preparing them for life in a highly technical society.

Converging with these concerns of the teachers was a national and statewide discontent with the character and nature of science taught K-12. This was documented in three national studies of science teaching and curriculum supported by the National Science Foundation and conducted in the late 1970's. The problems with science education revealed by these three studies were summarized in **Project Synthesis** (Harms and Yager, 1981). It made four general recommendations about needed changes in K-12 science curriculum. These recommendations are contained under four goal clusters:

> **Goal Cluster I - Personal Needs:** Science education programs should prepare individuals to use science for improving their own lives and coping with an increasingly technological world.

Recommended topics under this goal cluster are energy, population, human engineering, environmental quality, use of natural resources, space research and national defense, sociology of science, and effects of technological developments.

> **Goal Cluster II - Societal Needs:** Science education programs of the community should prepare its citizens to use science to deal responsibly with science-related societal issues.

The same topics were recommended under this goal cluster. Future citizens should be prepared to understand the relationship between the use of energy, for example, and its impact on society.

> **Goal Cluster III - Academic Knowledge of Science:** Science education programs should insure the continued development and application of scientific knowledge by maintaining a "critical mass" of fundamental scientific understanding in the American public.

Attention must be paid to the development of an adequate background in science relating especially to the content goals in clusters I and II. The future citizen must be prepared to understand the tentative nature of scientific knowledge. Programs must provide an opportunity for the citizen to gain current knowledge in science.

> **Goal Cluster IV - Career Awareness and Education:** Science education programs of the community should insure the continued development and application of scientific knowledge by maintaining a continual supply of citizens with scientific expertise.

This goal can be achieved through developing an appreciation for career opportunities in science, helping the student make career decisions and by providing a broader and more holistic view of science and technology.

In 1987, the American Association for the Advancement of Science sponsored a program to fundamentally change science as taught in American schools. Five panels of scientists met over a two-year period to define the content and character of "*Science for All Americans.*" This became the title of the report of **Project 2061** (AAAS, 1989). Much of the science content recommended was already found in school curricula. It differed, however, in two fundamental ways. First, the traditional boundaries between the disciplines of earth science, biology, physics, chemistry and mathematics are softened and the connections emphasized. Second, "the amount of detail that students are expected to retain is considerably less than in traditional science ... courses. Ideas and thinking skills are emphasized at the expense of specialized vocabulary and memorized procedures." The following recommendations were especially pertinent to the Worthington teachers' concerns regarding the existing high school science curricula:

> To ensure the scientific literacy of all students, curricula must be changed to reduce the sheer amount of material covered; to weaken or eliminate rigid subject-matter boundaries; to pay more attention to the connections among science, mathematics, and technology; to present the scientific endeavor as a social enterprise that strongly influences--and is influenced by--human thought and action; and to foster scientific ways of thinking.
>
> The effective teaching of science ... must be based on learning principles that derive from systematic research and from well-tested craft experience. Moreover, teaching related to scientific literacy needs to be consistent with the spirit and character of scientific inquiry and with scientific values. This suggests such approaches as starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypotheses, the collection and use of evidence, and the design of investigations and processes; and placing a premium on students' curiosity and creativity.

In Chapter 13, *Effective Learning and Teaching*, of the Project 2061 report the following recommendations are made:

Teaching Should Be Consistent With the Nature of Scientific Inquiry

Start With Questions About Nature
Engage Students Actively
Concentrate on the Collection and Use of Evidence
Provide Historical Perspectives
Insist on Clear Expression
Use a Team Approach
Do Not Separate Knowing From Finding Out
De-emphasize the Memorization of Technical Vocabulary

Science Teaching Should Reflect Scientific Values

Welcome Curiosity
Reward Creativity
Encourage a Spirit of Healthy Questioning
Avoid Dogmatism
Promote Aesthetic Responses

Science Teaching Should Aim to Counteract Learning Anxieties

Build on Success
Provide Abundant Experience in Using Tools
Support the Roles of Girls and Minorities in Science
Emphasize Group Learning

Science Teaching Should Extend Beyond the School

Teaching Should Take Its Time

In developing the new BESS curriculum and teaching approaches, the Worthington teachers took to heart most of the recommendations of Project 2061. These recommendations are also determining the nature of the National Standards for Science Teaching and Learning that are being developed by the National Research Council. They have also heavily influenced the new Ohio state standards for science that will be published shortly (see Appendix).

The National Academy of Science through its research arm the National Research Council is completing a two-year study leading to recommendations for national standards for science. The standards are being developed (NRC, 1994) in five areas; content, teaching, assessment, program and system. The development of standards in these areas is guided by the following principles:

All students must have the opportunity to learn the science defined in content standards.

With appropriate opportunities and experiences, all students can learn this science.

Students should learn science in ways that reflect the inquiry used by scientists to understand the natural world.

Learning is an active process that occurs best when each student acts as a member of a learning community.

The quantity of factual knowledge and routine skill must be limited to what is essential or fundamental so that students have the time to attain deep understanding and the thinking power defined in the content standards.

Content, teaching, and assessment standards guide the central features of an education program. The application of these standards and their interactions in a specific place and time provides students with the opportunity to learn what is defined in the content standards.

The **content** standards are being developed in the following areas; science as inquiry, physical science, life science, earth and space science, science and technology, science and societal challenges, history and nature of science, and unifying concepts and processes. There are five areas of **teaching** standards designed to define how science is presented in the classroom. An example is:

> Teachers establish a learning community that engages each student consistent with scientific habits of mind, attitude, and values through: a respect for ideas and experiences, student voice in decisions and responsibility for learning, a collaborative approach to experiences and learning, and shared understanding of the rules of scientific discourse.

There are several areas also being defined in the **assessment** standards. The following speaks most directly to the nature of assessment in the classroom:

> Assessment activities focus on the science that is most important for students to learn: ability to inquire, understand subject matter, use knowledge to solve problems, and communicate about scientific ideas.
>
> Every aspect of the assessment process must be consistent with the purposes of the assessment and be presented in ways that elicit the kinds of understandings, reasoning, and communication that are a part of the science that is assessed.

These assessment standards imply the use of the types of alternate assessment techniques being used by many BESS teachers, including portfolios, rubrics and performance testing.

The standards also speak to the overall school **program**; that science should be coordinated with mathematics; that students and teachers have access to the necessary, time, space materials and personnel; and that,

> science education programs provide an opportunity to learn science in a community of learners that values scientific attitudes and habits of mind and the social values to learn science. It promotes the ability to work in groups, and extends responsibility for learning to the student.

The **system** standards will speak to issues such as; resource allocation must be consistent with program standards and principles of equity; and coherent and consistent communication must occur among and between system levels aligned with content, teaching, and assessment standards.

The fact that the BESS program as originally designed by the Worthington teachers follows closely the elements of content, teaching and assessment included in this most recent version of the National Science Standards speaks well for the teachers' insight and their understanding of the needs of their students in science.

One other report has relevance to the BESS program. The Secretary's Commission on Achieving Necessary Skills (SCANS) was appointed by the Secretary of the Department of Labor to "determine the skills that our young people need to succeed in the world of work." Its report (SCANS, 1992) lists five **workplace competencies**, including the following:

> **Resources** - Workers "will know how to allocate time, money, materials, space, and staff."
>
> **Interpersonal Skills** - Workers "can work in teams, teach others, serve customers, lead, negotiate, and work will with people from culturally diverse backgrounds."
>
> **Information** - Workers "can acquire and evaluate data, organize and maintain files, interpret and communicate, and use computers to process information."
>
> **Systems** - Workers "understand social, organization, and technological systems; they can monitor and correct performance; and they can design or improve systems."

The report also listed three areas of **foundation skills** required by the worker. They include;

> **Basic Skills** - reading, writing, arithmetic and mathematics, speaking, and listening.
>
> **Thinking Skills** - the ability to learn, to reason, to think creatively, to make decisions, and to solve problems.

Personal Qualities - individual responsibility, self-esteem and self-management, sociability, and integrity.

Again, the BESS program, as originally designed, addresses many of these needs of the workplace. The program was designed to help in the development of these personal capabilities that all students must acquire whether they will be working in a fast food restaurant or in a science research institute in a university or industry.

Part II - Development and Implementation of the BESS Program

The School Board, through the assistance of Ohio State University, obtained about $300,000 of funding from the FIRST program of the Office of Educational Research and Innovation of the U.S. Department of Education to support the development and implementation of the BESS program. This provided release time for teachers to identify materials, and to develop curriculum frameworks for the course. In addition the grants provided for a National Advisory Board and an evaluation program. Additional funding came from other sources, including two Eisenhower grants, totaling about $100,000, obtained by Dr. Rosanne Fortner, an Ohio State University Professor and a BESS parent, which provided in-service preparation for the Worthington teachers. It also helped to create awareness of the program among other high school science teachers in the central Ohio region. A Community Advisory Board, including scientists from The Ohio State University and the Ohio Department of Natural Resources who were also Worthington parents, was empaneled in 1990 to help in guiding the development of the program. In 1993, a Parent Advisory Board was created to provide assistance to the K-12 science program of the Worthington Schools.

Because of the exemplary nature of the course and of the teachers who have implemented it, The Ohio State University College of Education has designated the BESS program as one of its two science education Professional Development Sites. Mark Maley, BESS teacher, was named a Clinical Educator. He is supported 40% time by the University and assists in its pre-service program for science teacher preparation. He supervises pre-service teachers in their school experiences in the BESS program and participates in the teaching of a science methods program at the University during the Autumn Quarter.

The Worthington District is fortunate to have had the amount and quality of personnel and material support in creating and carrying out a new curriculum. Seldom has a district marshaled the national, state and local assistance for its teachers and administrators to the extent that has been possible for the BESS program. It now serves as a national model, not only for the BESS curriculum design, but also for the process used in its development and implementation. It also serves as an exemplary model for pre-service teacher preparation through the cooperation of the Worthington Schools in the Professional Development Site program of The Ohio State University. Inquiries about the program have been received from over 75 school districts distributed among all regions of the United States.

Part III - Evaluation

As with any new program, there are concerns among teachers, administrators and parents as to its quality and its effectiveness in serving the educational needs of the community. Accordingly a varied evaluation program was conducted by the Science Education Program of OSU. A question asked early in the start of the program was: To what extent did the content taught in the BESS program differ from that of the traditional science curriculum? To answer this question, two types of multiple choice instruments were given to BESS I and II students to monitor any changes in traditional knowledge. They were portions of the earth science and biology tests developed by the National Science Teachers Association (NSTA) in the mid-1980's. A 25% random sample of the students enrolled in BESS I and BESS II completed each of the assessment instruments. BESS II students scored at the national mean on the earth science test and just below it on the biology test. BESS I students scored somewhat lower on certain portions of each test suggesting that the BESS program helped students in learning much of the content of the traditional curricula, but also departed in significant ways. Although several attempts were made to develop an instrument that would measure BESS content achievement directly, insufficient time and resources were available to develop an instrument that the BESS teachers could agree upon.

Additional evaluations were conducted through the doctoral program in science education at Ohio State. Such students in the first or second year of their program are required to engage in two research or evaluation experiences under a faculty mentor. Through this program two instruments were developed and administered. One was constructed to identify student understandings of the goals of BESS and their attitudes toward the course. Another instrument with similar objectives was developed for parents. Both were administered in May and June of 1993.

Student Survey. The student survey consisted of 80 statements and was given to all students enrolled in the BESS program during class time by their teachers during the final week of the 1992-1993 school year. Students were asked on the survey the extent to which they agreed or disagreed with each statement on a five-point scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree). Values scored ranged from 1 for Strongly Disagree to five for a Strongly Agree response. The instrument was divided into 12 groups of similar statements for analyzing the results. Eight groups of items represent primarily the goals of BESS and can be considered to reflect students understanding of the content of the course. The remaining four reflect student attitudes toward certain aspects of the course. Usable responses to the survey were obtained from 892 Worthington students, about equally divided between BESS I and BESS II.

Course Goals. As seen in the chart below, in all cases the understanding of BESS students of the goals of the course was higher than a neutral response. Examples of items in each category follow:

Interrelations: In science class we learn how human activities, such as the burning of fossil fuels, affect the natural environment.

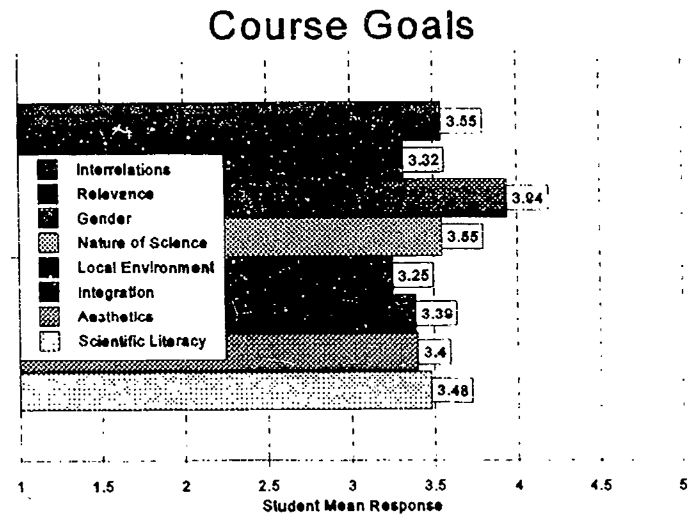
Relevance: Many of the things we have studied in science class are important to my everyday life.

Gender: Boys and girls should have equal opportunities as they grow up to have a career in science.

Nature of Science: Scientific facts are often subject to change.

Local Environment: As a result of my science class, I pay more attention to the natural world around me

Integration: Combining information from all of the sciences makes solving problems about the Earth easier.



Aesthetics: I appreciate the beauty of Earth and its processes more now than I did a year ago.

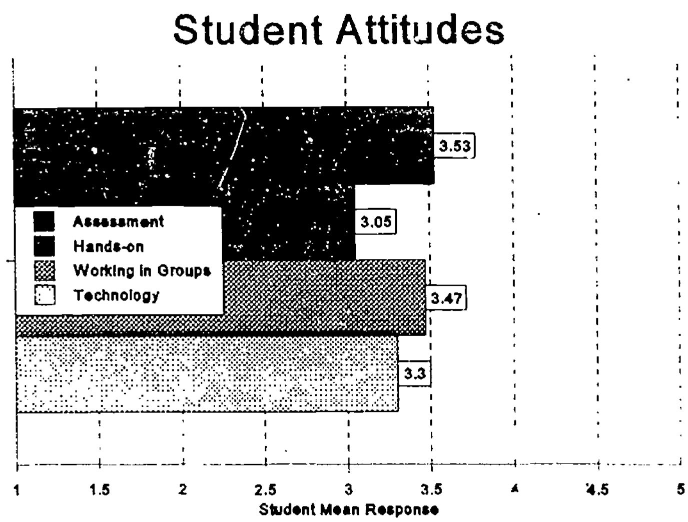
Scientific Literacy: When reading a science related article I can judge whether it is scientifically correct.

Further analyses were done to find if there were any statistically significant differences between BESS I, BESS II, BESS I Enriched and BESS II Enriched groups on any of the variables. This analysis is portrayed in the table below.

VARIABLE	REGULAR I	ENRICHED I	REGULAR II	ENRICHED II
Local Environment	higher	--	lower	lower (3.12)
Scientific Literacy	higher	--	lower	--
Nature of Science	higher	--	lower	--
Gender	higher	higher (4.05)	lower	--
Relevance	higher	--	lower	lower
Interrelations	--	higher	lower	--

In all cases, all groups scored above the neutral (3.0) response with the lowest being 3.12 by Enriched BESS II on the *local environment* variable and the highest being 4.05 by the Enriched BESS I group on the *gender* variable. Although there were variations between the four groups of students on certain variables, all BESS groups seemed to have an adequate understanding of the goals of the program since none of the group means fell below the neutral (3.0) score. There certainly were wide variations among individual students as to their understandings of those goals as one might expect in any program.

Student Attitudes. Student attitudes toward four aspects of the BESS course can be seen in the chart to the right. Students seemed to be satisfied with the course, with neutral attitudes toward the *hands-on* aspect of the course and more positive attitudes toward *working in groups*, *assessment* techniques, and the use of *technology*. Typical statements in each group of items are:



Assessment: I like the fact that the letter grade that I get in science class is based partly on grades from working in teams.

Hands-on: I have enjoyed working on projects in science class.

Working in Groups: Interacting in a group with other students helps me learn science.

Technology: Using computers makes learning science easier.

The analysis by groups on these four variables yielded several statistically significant differences. The enriched and regular BESS II groups were less positive toward the *technology* aspect of the course than the regular BESS I group. The enriched I group was more positive on this variable than the regular BESS I group. The BESS I group was more positive toward *working in groups* than was the enriched II group. Both enriched groups and the regular BESS I group were more positive on the *assessment* aspect of the course then was the regular BESS II group. The lowest attitudes were on the *hands-on* nature of the course. Both enriched groups and the BESS II group had the only scores below 3.0 on any of the variables. They were significantly lower than the BESS I group on this variable. Group scores ranged between a low of 2.88 by the enriched II group on the *hands-on* variable and 3.64 by the enriched I group on the *assessment* variable.

From this analysis it seems that all of the BESS groups were satisfied with the nature of the presentation of the BESS course. Even the lowest rated variable, *hands-on,* was essentially a neutral response. But it is one aspect of the course that teachers might want to pay special attention to as they continue to work to improve the BESS program.

Parent Survey. A similar survey instrument was constructed for use in determining parent knowledge of and attitudes toward the BESS program. It consisted of 50 items. A 25% random sample of parents, stratified by student class, was selected to receive the survey by mail at the end of the 1992-3 school year. A follow-up mailing was sent to the non-respondents on the first mailing. Final response rates are shown in the following table:

SCHOOL	SAMPLE	RESPONSE	RATE
Kilbourne	161	79	49 %
Worthington	154	70	45 %
Linworth	16	8	50 %

Response rates for parents of students in the enriched classes were much higher than from those parents of students in the regular BESS classes. From Kilbourne parents for example they were 82% and 59 % for the enriched and 48% and 39 % for the regular. For the Thomas Worthington parents they were 65% and 65% for the enriched and 44% and 36% for the regular. The overall response rate exceeded the expectations of both the evaluation team and the Worthington administration.

A factor analysis of the data yielded three clear factors. One focused on the goals of the course and included 16 items, the second on parent attitudes toward the BESS course, and the third on parent knowledge and background in educational issues. The following differences between groups were significant; understanding of the goals of BESS, a low of 3.43 among the Thomas Worthington parents and a high of 4.04 among the Linworth parents; parent background, a low of 3.29 among the BESS I parents to a high of 3.46 among the BESS II parents. Differences between the responses to individual questions on the survey were found for the parents of students enrolled in regular BESS classes and those of students enrolled in the enriched classes. The items that yielded statistically significant differences are included in the table below:

STATEMENT	REGULAR	ENRICHED
Course Goals:		
The BESS sequence promotes good laboratory skills.	3.53	3.04
The BESS sequence encourages leadership in students.	3.43	3.08
The BESS program should definitely be continued	3.56	3.12

Parent Attitudes Toward BESS:		
My child is better off taking the BESS sequence rather than a conventional Earth Science/ Biology sequence.	3.08	2.67
I have heard good things about the BESS program.	3.11	2.57
I have heard negative remarks concerning BESS.	3.26	3.98
My child does NOT find his/her BESS class to be very meaningful.	2.89	3.45
Students should have the option of bypassing the BESS sequence to enable them to take more Advance Placement courses.	3.18	3.61
The effect of a science course on a student's attitude does NOT really influence whether he/she will continue to learn more about science.	2.12	1.78
Science curriculum reform is unnecessary.	2.31	1.96
Parent Background:		
My child plans to attend college.	4.8	5
I am quite knowledgeable about the BESS curriculum and approach to learning science.	2.81	3.24

From the data in the table above the following conclusions can be drawn. The parents of students enrolled in the regular BESS course seem satisfied that their children are having an appropriate and positive educational experience. The parents of students enrolled in the enriched classes are neutral to slightly negative as to their attitudes about the quality of the BESS program. There might be discussion among parents about the BESS program, especially among the parents of students in the enriched BESS classes, which tends to be somewhat negative toward the course. Parents of the students enrolled in the enriched sections of BESS want their children to take Advanced Placement courses, and may see the BESS program as an obstacle. From written comments on some survey forms, evidently there were some problems with instruction in the enriched classes. Building principals made adjustments to correct some of these problems for the following school year. Apparently the concerns of the parents in those classes may have influenced their responses to the survey, possibly leading to less positive (or more negative) attitudes toward the program then otherwise might be expected.

VI. BESS National Advisory Committee Meeting - February 4, 1994

The National Advisory Board has met three times since 1991. Dr. Paul DeHart Hurd, Professor Emeritus from Stanford University, America's "Dean of Science Education," and one of the foremost thinkers about science education curriculum and teaching, serves on this panel. Also, Dr. Audrey Champagne, Professor of Chemistry and Science Education at SUNY Albany and Chair of the Assessment Panel of the NRC Science Education Standards Committee served on the Board. Additional members include high school science teachers and administrators from ten central Ohio school districts. The most recent and probably final report of this group follows in section V of this Report. The meeting resulting in this report was held Thursday and Friday, February 3 and 4 at the facilities of the National Center for Science Teaching and Learning on the Ohio State University campus.

Representatives from groups other than the National Advisory Committee were also in attendance as observers at the meeting. These groups included the steering committee of the BESS parent advisory committee, the Community Advisory Group, BESS teachers, Worthington Schools Administrators (Arnold Skidmore and William K. Northrup), and science educators from the Ohio State University. Representatives from these groups participated fully in the discussions of both the Task Force groups and the entire group. Their concerns and ideas were taken under consideration by the advisory committee members in making their recommendations.
BESS teachers were asked to provide the committee with a set of concerns with which we could deal. The committee members and observers were divided into five Task Force groups to consider these concerns.

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The concerns related by the teachers included: How can the quality of the BESS program be assessed and expressed?, Who are the important players in that assessment?; What reference materials can/should be supplied for BESS students in the district?, How will such materials be obtained?; How can "exceptional" science students be identified?, What type of science program would best fit their abilities?; How can the scheduling of classrooms and teachers be done to maximize the use of available resources, including time?; Should there be alternatives to BESS offered to students?, and How might the state mandated proficiency test affect BESS?

In an afternoon session, the Task Force groups also considered some additional concerns. One dealt with potential models of school organization that would allow teachers to have the time to organize and prepare curriculum elements, stay current, and to consult with their colleagues. Others dealt with budgeting and how parents might become aware of current educational research about science teaching and learning and the national programs that are in the process of reforming science education.

V. RECOMMENDATIONS

Assessment. To begin an assessment of the quality of BESS it is necessary to identify the indicators of a high quality science curriculum in terms of the attributes indicated by research and national curriculum review projects that are integral to such high quality programs. These are engendered in the goals of BESS, including:

1. Relevance (of the curriculum to the students in our world).
2. Integrated disciplines.
3. Increased use of technology.
4. Use of constructivist modes (knowledge is constructed by each learner) - reflected by the curriculum being posed as sets of questions.
5. Student team work.
6. Communications skills emphasized on several levels.
7. Students involved in community service.

In addition, there is a list of learner outcomes developed by the teachers that should be used as a basis of determining the quality of BESS. All stakeholders: teachers, students, parents, and business owners should be assessed. The assessment of these groups of people might be done using an evaluation instrument with a dual Likert scale. The items could be developed using the goals of BESS and the learner outcomes. The first of two Likert scales could address the perceived level of importance of each of the outcomes and goals and the other scale could reflect the perceived level of implementation of each learner outcome or BESS goal. All instruments should have an open-ended feature for students to add what more they feel they know or can do.

Parents and the community need to be kept informed of the types of assessment in progress and their results. Additional measures of success should include qualitative studies. Care should be taken not to over test the students by constructing new surveys for every concern. Providing an outline of studies completed and in progress should assure all parties that adequate analyses are being done.

Materials. The materials needed for a curriculum project like BESS are varied. The BESS teachers do not see the need for a one-book-per-student textbook. There are no textbooks that fit the purpose/goals of BESS. Classroom sets of traditional texts are kept, but there has been a security problem. Some books have disappeared. There is a need, however, for resource materials for students. Some of these belong in the classroom, some in the school library and some for the students to carry with them. The needs at each building may be different. What must be done is that teachers need the time and financial resources to pursue and develop the relevant resources for BESS. The result could be a resource "notebook" or "folder" that could be used throughout the year. Other resources need to be accessed, including CD-ROM, on-line data bases, videos, videodisc, and a wide variety of printed materials. Time, money and personnel resources need to be assigned to these as well. Student access to materials may be enhanced by extending the hours of the school library. Perhaps it could be open in the evening and even available to the general public.

BESS requires a wide variety of materials that need to be replenished and added to each year. The types of resources used in BESS must be current. Many of the topics, especially the environmental concerns, are rapidly expanding areas of research. The amount of new information being generated annually is huge. There is a concern that shrinking budgets will not allow teachers to get the current resources needed to keep up with what is going on in scientific research. An on-going, adequate supply of funding is needed. This could be supplemented with grant money, perhaps from Eisenhower funds, the Ohio Environmental Education Fund and other similar sources. Additional sources of money for BESS could also include business partnerships (Science Advisory Board will look into this) and technology grants.

Time Needs. Many BESS teachers are spending inordinate amounts of time shuffling materials and equipment from room to room and place to place. There must be adequate materials and research resources to supply all of the BESS classrooms so that all the needs of BESS can be met without moving things around. There should also be enough BESS classrooms so that sharing rooms is minimized or eliminated. The time wasted by the BESS teachers could be used to begin the resource development process described above and to confer with their colleagues to share successes and failures. If BESS teachers were given no more than four classes per day it would provide them with much of the needed time necessary for such an innovative and nationally recognized program as BESS.

Time could also be saved by having a copy machine in the science department. This would be a back-up to the long-term needs that could still go to the district copy center. Other time-savers could include computers in a central location staffed by a science teacher, the teacher work center could be located closer to the BESS classrooms, and teacher duties for BESS teachers should be science duties (like the computer center mentioned above).

There is a lack of space as a result of increased enrollment and a consequent loss of available resources, especially at Thomas Worthington. To help alleviate the problems of space and time, teachers could work as a team, especially since the students in BESS are expected to work in teams. Perhaps units, at least in BESS I, could be flip-flopped as much as possible among the BESS I teachers so that there is less demand on the resources for a particular unit at one time. Again, many of these problems can be worked out by the teachers if they have the time and opportunity to work together on a regular (preferably daily) basis.

Finally, we recommend that BESS teachers be given early release days in order to work together to improve the curriculum. They should have some common time at lunch or common planning time as much as possible to be able to plan and implement an evolving curriculum.

Field Trips. Real world experience is an integral part of BESS. This makes field trips absolutely essential for meeting the goals of the program. It is necessary for BESS teachers to get their students out in the field or community to have reality based experiences at least once each quarter.

Articulation. There is a concern that with a new science curriculum in the middle schools, there may be a problem with articulation among the middle schools and the high schools. We understand that the district is sponsoring meetings to facilitate this articulation. We recommend that some of the BESS teachers have an active role in this articulation effort. It will take meeting and planning time for teachers and administrators in order for effective articulation to occur.

Alternatives. "Exceptional" science students need to be a part of BESS. BESS is a curriculum for all students. All citizens in the United States need a background not only in science but in how science relates to the real world and the organisms (including humans) that live in it. All people need an appreciation of how humans affect the environment and how they are affected by it in return. BESS does this. BESS also helps students to learn to work together for a common goal. This is a skill needed by all people in a world where work is being accomplished almost always in teams.

There should not be any alternatives to BESS other than what already exists - BESS I, BESS II and Enriched. There should not be a one-year BESS that combines BESS I and II together. Long-term, meaningful learning takes time. Putting BESS into one year does not provide students with the adequate time to achieve the goals and learner outcomes of BESS.

We recognize that exceptional students often need additional opportunities for exploration and challenge. These challenges can be met within BESS in a variety of ways, including increased access to the technology (computers, CD-ROM, on-line data bases), the use of projects, community service, and perhaps a science club. Students are challenged when they are able to go deeper into a subject, especially on individual projects.

There is a great deal of parental interest in Advanced Placement courses in science. There is a perception shared by a few students and parents that a student needs as many AP courses on his or her high school transcript as possible in order to be accepted by the best universities. We know of no evidence that supports this perception. In fact, those of us who teach AP courses often see students who proficiency out of an entry level college course begin their higher level education at a disadvantage. The AP course and exam do not always cover all of the material required in a beginning-college course at a particular university.

As an alternative to AP courses, the school district should strive to make parents aware of the Concurrent Enrollment Program with The Ohio State University. Here talented students can enroll in regular university courses and receive both high school and university credit. It provides them with university quality instruction and transferable university credit at no cost to the student. Information can be obtained from The Academic Program unit of the University's Admissions Office. Enrollment in this program, as an alternative to the AP courses that are currently offered, would help to alleviate some of the pressure on BESS and the rest of the high school curriculum.

Regardless of the discussion of AP courses, all students need to deal with the topics offered in BESS because they are important for scientific literacy. Students will not get many of these topics in other courses. Students also learn how to work together in teams in BESS. The skills necessary to do this are becoming increasingly important in the real world of work and life in general.

There already exists an alternative to BESS. It is BESS Enriched. The needs of those students who are exceptional in science can be met within the Enriched program. A proposal to have BESS "condensed" into a one year program for some students will not allow those students the appropriate amount of time to learn the diverse nature of Earth Systems in a meaningful way. We recommend that BESS remain a two year program for all students.

Organizing. Concerns about the amount of content material dealt with in BESS are unwarranted. The material is dealt with deeply and with a great deal of richness that is often lacking in a traditional science course. Learning to learn and learning to work with others is an important aspect of BESS and this is where the resources of the district may need to be focused. Teachers need more time and money to plan, to work collaboratively with colleagues and to have in-service opportunities to further develop their skills in helping students in these areas. When these skills are further developed, then the kinds of experiences for all students in BESS will be improved and the appropriate balance of content and process can be maintained.

To address the concern about organizing and staffing, it is necessary for teachers to get together on a regular basis. This could be accomplished through such creative scheduling options as block or flex scheduling, or having integrated classes with the teaming of teachers. Teachers could have early release times to meet as a department or by building. Regular in-service days (i.e. COTA Day) should be used for this purpose as well.

Teachers need to have their own room as much as possible. They need common planning times, and any duties they have should be science duties. To facilitate communication, the different buildings should be networked electronically so that all of the teachers can be in touch with all of the others if necessary.

Parent Awareness. Parent education about BESS can be facilitated by inviting them to advisory and committee meetings like this national meeting and by having a library of selected educational journal articles and materials from NSTA and ASCD for parent use. Perhaps students could do presentations to parents in an open house kind of setting to demonstrate the knowledge and skills gained in BESS.

EPILOGUE

The members of the BESS National Advisory Committee wish to commend the efforts of the BESS teachers and the Worthington Schools administrators in developing and implementing the BESS program. It has taken a great deal of hard work and personal sacrifice on their part to be at the leading edge of science education reform. We also commend and thank Arnie Skidmore and Bill Northrup for their participation in the meeting and for their unique insights into BESS.

The goals of BESS echo the major goals of such national curriculum reform efforts as Project 2061 of the American Association for the Advancement of Science and Earth Systems Education based at Ohio State and the University of Northern Colorado. Since BESS was being developed simultaneously with these projects, the BESS teachers did a great job in anticipating the goals of the future in science education. This is one reason why BESS is a model of an exemplary science curriculum. Another reason is the work and dedication of the teaching and administrative staff of Worthington Schools.

BESS has been evolving and will continue to evolve as long as the information from scientific research grows and as the teachers grow professionally. The opportunity for teachers to keep up with these two aspects of growth needs to be nourished.

BESS has gained national recognition through PLESE (Program for Leadership in Earth Systems Education). It has also been the example to follow for two local Eisenhower funded Earth Systems projects, one for nine school districts at the middle school level and the other for ten districts at the high school level. As a result of these projects, earth systems concepts are being increasingly used in school districts in central Ohio.

The members of the National Advisory Committee wholeheartedly endorse the goals of BESS and the work of the BESS teachers. We recognize that no curriculum is perfect and that BESS can be improved. It is hoped that the recommendations made by this committee will help with this improvement.

The names of the people on the National Advisory Committee are listed below. They are unanimous in their support of the foregoing recommendations.

Dr. John Conrath
Superintendent
Whitehall City Schools

Dr. Melissa Conrath
Assistant Superintendent
Gahanna Public Schools

Carol Damian
Physics Teacher
Dublin High School

Susan Godez
Teacher
Grandview Heights High School

Dr. Colleen Huckaby
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References

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

FCCSET Committee on Education and Human Resources (1991). **By the Year 2000: First in the World.** Washington, D.C.: Executive Office of the President, Office of Science and Technology Policy.

Harms, Norris C. and Yager, Robert E. (1981). **What Research says to the Science Teacher; Volume 3.** Washington, D.C.: The National Science Teachers Association.

National Research Council (1994). **What are National Education Standards?** Unpublished Summary of the National Science Standards.

Secretary's Commission on Achieving Necessary Skills (1992). **Learning a Living: A Blueprint for High Performance.** Washington, D.C.: U.S. Department of Labor.

APPENDIX

A. Current draft outline of the National Science Standards of the National Research Council

B. Excerpts from the current draft of the Ohio Science Standards

C. Speech of Dr. Paul DeHart Hurd to the BESS Advisory Committee entitled "Postmodern Science and the Responsible Citizen in a Knowledge-Intensive Era"

D. Article on "Biological and Earth Systems Science" from **The Science Teacher**

National Science Education Standards

"Headline" Summary

National Research Council

February 17, 1994

What Are National Education Standards?

"Standards" are statements that can be used to judge quality.

National Standards in Science Education

- CONTENT STANDARDS
  define what all students should know and be able to do as a result of their school learning experiences. They are voluntary, not federally mandated nor reducible to a set of minimum competencies.

- TEACHING STANDARDS
  provide a vision of what teachers need to understand and do to provide learning experiences for students that are aligned with content standards. They do not describe one best way to teach or learn.

- ASSESSMENT STANDARDS
  identify essential characteristics of fair and accurate student tests, assessments, or program evaluations that are consistent with content standards at the learning, school, district, state, and national levels. They are not tests nor do they describe a single strategy to judge student learning or a school program.

- PROGRAM STANDARDS
  describe how content, teaching, and assessment are coordinated in school practice over a full range of schooling to provide all students the opportunity to learn science.

- SYSTEM STANDARDS
  describe how policies and practices outside of the immediate learning environment support high quality science programs.

Science Education Standards Are Guided By These Principles:

- All students must have the opportunity to learn the science defined in content standards.
- With appropriate opportunities and experiences, all students can learn this science.
- Students should learn science in ways that reflect the inquiry used by scientists to understand the natural world.
- Learning is an active process that occurs best when each student acts as a member of a learning community.
- The quantity of factual knowledge and routine skill must be limited to what is essential or fundamental so that students have the time to attain deep understanding and the thinking power defined in the content standards.
- Content, teaching, and assessment standards guide the central features of an education program. The application of these standards and their interactions in a specific place and time provides students with the opportunity to learn what is defined in the content standards.

Working Outline -- **National Science Education Standards**

Part I. An Integrated Presentation of Content, Teaching, and Assessment

Kindergarten through Grade 4, Grades 5-8, and Grades 9-12
Learning, Teaching, and Assessing Science
Science Content Standards:

- Science as Inquiry
- Physical Science
- Life Science
- Earth and Space Science
- Science and Technology
- Science and Societal Challenges
- History and Nature of Science
- Unifying Concepts and Processes (K-12 only)

Part II. An Analytical Presentation of Science Education Standards

1. Program Standards
2. Teaching Standards
   - Teaching
   - Professional Development
3. Content Standards
4. Assessment Standards
5. System Standards

SCIENCE EDUCATION CONTENT STANDARDS

	Science As Inquiry	Physical Sciences	Life Sciences
K-4	♦ Ask for information to answer a question ♦ Plan and conduct a simple investigation ♦ Employ simple equipment and experiences to gather data ♦ Use data to construct a reasonable explanation ♦ Communicate investigations and explanations	♦ Properties of Objects and Materials ♦ Position and Motion of Objects ♦ Forms of Energy: Heat, Light, Electricity, and Magnetism	♦ Characteristics of Organisms ♦ Life Cycles of Organisms ♦ Organisms and Environments
5-8	♦ Identify questions for scientific investigations ♦ Design and conduct a scientific investigation ♦ Use appropriate tools and techniques to gather, analyze, and interpret data ♦ Construct explanations and models using evidence ♦ Think critically and logically about the relationships between evidence and explanations ♦ Recognize and analyze alternative explanations and procedures ♦ Communicate scientific procedures and explanations	♦ Properties of Matter ♦ Particulate Model of Matter ♦ Motions and Changes in Motion ♦ Transformations of Energy	♦ Cells and Multicellular Organisms ♦ Heredity, Reproduction, and Development ♦ Diversity and Adaptation of Organisms ♦ Ecosystems and Organisms
9-12	♦ Identify questions and concepts that guide scientific investigation ♦ Design and conduct full scientific investigations and communications ♦ Use technologies to improve investigations ♦ Construct and revise scientific explanations and models using logic and evidence ♦ Recognize and analyze alternative explanations and models ♦ Communicate and defend a scientific argument ♦ Analyze a historical or contemporary scientific inquiry	♦ Structure of Matter ♦ Chemical Interactions ♦ Forces and Motion ♦ Conservation and Transmission of Energy	♦ Diversity of Structure and Function ♦ Cells as the Unit of Life and the Formation of Multicellular Organisms ♦ Principles of Heredity ♦ Evolution of Life ♦ Matter and Energy ♦ Populations and their Interdependence

SCIENCE EDUCATION CONTENT STANDARDS

	Earth and Space Sciences	Science and Technology	Science and Societal Challenges
K-4	♦ Properties of Earth Materials ♦ Objects in the Sky	♦ State a Problem ♦ Design and Implement a Solution ♦ Communicate the Problem, Design and Solution ♦ Evaluate the Solution	♦ Characteristics and Needs of a Population ♦ Types of Resources ♦ Change in Environments ♦ Personal Actions
5-8	♦ Interactions and Cycles in the Earth System ♦ Earth's History ♦ Earth in the Solar System	♦ Process of Technological Design ♦ Connections between Science and Technology ♦ Similarities and Differences between Scientific Inquiry and Technological Design	♦ Population, Resources and Environments in Societies ♦ Natural Hazards ♦ Technology and Society ♦ Risks and Benefits ♦ Personal Decision Making
9-12	♦ Matter and Energy in the Earth System ♦ The Evolution of the Earth System ♦ Earth in the Universe ♦ Geochemical Processes and Cycles in the Earth System	♦ Nature of Technology ♦ Process of Technological Design ♦ Interactions between Science and Technology ♦ Similarities and differences between Science and Technology	♦ Population Growth ♦ Natural Resources ♦ Environmental Degradation ♦ Natural and Human-Induced Hazards ♦ Community Health ♦ Global Change ♦ Science, Technology and Public Policy

	History and the Nature of Science	Unifying Concepts and Processes of Science
K-4	♦ Scientific Inquiry ♦ Science as a Human Activity	♦ Systems ♦ Organization ♦ Form and Function ♦ Interactions ♦ Change ♦ Measurement ♦ Models ♦ Scale ♦ Adaptation ♦ Explanation
5-8	♦ Scientific Inquiry ♦ Science as a Human Endeavor ♦ Science and Society	
9-12	♦ Scientific Inquiry ♦ Scientific Explanations ♦ Nature of Scientific Knowledge ♦ Revolutions in the History of Science	

Teaching Standards

- Teachers set goals, plan, and design science learning experiences, guided by the content standards; an understanding of how science is taught and learned; and the particular interests, knowledge, and experience of each student.

- Teachers guide and facilitate learning by interacting with students, orchestrating discourse, recognizing diversity and engaging all students in learning experiences, challenging students to be responsible individual and collaborative learners, and providing students with exemplary habits of thinking, curiosity, and creativity.

- Teachers assess learning and analyze teaching on an ongoing basis to guide students, teaching practices, and to monitor and record student development.

- Teachers establish a learning community which engages each student consistent with scientific habits of mind, attitude, and values through: a respect for ideas and experiences, student voice in decisions and responsibility for learning, a collaborative approach to experiences and learning, and shared understanding of the rules of scientific discourse.

- Teachers provide students with time, space, resources consistent with science learning: extended investigation, in-depth inquiry, flexible exploration, hands-on investigation, safe setting, appropriate print and material resources, out-of-school resource use, and opportunities for student designed investigation.

Professional Development Standards

- Teachers learn science content through the perspectives and methods of inquiry.

- Teachers are enabled to integrate their knowledge of science, pedagogy, and young people and their learning; and apply this knowledge to their science teaching.

- Teachers build the skills and dispositions to engage in and commit to long-term learning, and to assess, analyze, and reflect on their knowledge and skill.

- Teachers experience a coherent learning program, whether designed by an individual teacher or by an institution (e.g. a university, school district, or other) aligned with the vision and concepts in the national science education standards.

- Federal, state, local, and professional association policies are coordinated to support the vision of science teacher development envisioned by national standards.

Assessment Standards

- Assessment activities focus on the science that is most important for students to learn: ability to inquire, understand subject matter, use knowledge to solve problems, and communicate about scientific ideas.

- Every aspect of the assessment process must be consistent with the purposes of the assessment and be presented in ways that elicit the kinds of understandings, reasoning, and communication that are a part of the science that is assessed.

- Valid inferences are made about the students' learning of science based on assessment information that can be generalized, is valid, and has the confidence of the public.

- Assessment practices are fair to all who are assessed by accommodating the needs of all students, avoiding language advantageous to any group, including a range of ethnic groups and both genders in development, and monitoring performance among sub-groups.

- The assessment process involves science teachers and other professionals in the design, development, and interpretation of assessment activities and the resulting information.

- The assessment process gives equal attention to the assessment of opportunity to learn and student attainment. Opportunity to learn will include teacher competence, equity treatment, support for teachers, and resources for teaching and learning.

- Design of the assessment process is determined by the intended use of the resulting information, e.g., guiding teaching and learning; promoting self-reflection among teachers and students; making decisions about individuals, groups or systems.

Program Standards

- The conten+ teaching, and assessment in school science education programs are aligned and articulated across levels to support clearly understood learning goals and expectations.

- The content selected for the science programs is consistent with developmental nature of students, emphasizes the acquisition of knowledge through inquiry, integrates the content standards in a variety of curricular patterns, and contains content from all standards.

- The science program of study should be coordinated with the mathematics program to enhance students' understanding of mathematics its use in the study of science.

- Students and teachers have access to appropriate and sufficient time, space, materials, equipment, and personnel.

- Science education programs provide an opportunity to learn science in a community of learners that values scientific attitudes and habits of mind and the social values to learn

(Program Standards cont'd.)

science. It promotes the ability to work in groups, and extends responsibility for learning to the student.

- All students in the K-12 science program must have equitable opportunities to achieve the National Science Standards by having access to facilities, material, and equipment; skilled teaching; and a heterogeneous community of learners.

System Standards

- System Standards align assessment policy with content, teaching, assessment, & program standards.
- System Standards match teacher preparation and certification policies with teaching standards.
- Communication among and between system levels is coherent and consistently aligned with content, teaching, and assessment standards.
- Resource allocation is consistent with teaching and program standards and is aligned with principles and standards of equity.

Working Draft

Model Competency-Based Science Program

Ohio Department of Education
Division of Curriculum, Instruction, and Professional Development

Working Draft January 20, 1994

Citation: *Model Competency-Based Science Program*. Columbus, OH: State Board of Education, 1994.

Cover: *This design expresses the significance of the wholeness of the universe while at the same time illustrates its complexity and diversity. Ohio's mammal, white tailed deer; insect, lady bug; and fossil, trilobite are representative of Ohio's diversity. Human involvement in environmental matters is represented by an industrial picture, the road leading to the mountains and the setting sun, the formulas human-kind has invented to explain relationships in the natural world, and the hand planting a seedling. The picture of the water planet (earth) invites every learner to discover its vastness and many secrets. The inquiry nature of science learning is aptly represented by the question mark.*

Philosophy and Goals

The mission of the State Board of Education is "to prepare all students of all ages to meet, to the best of their abilities, the academic, social, cultural, civic and employment needs of the twenty-first century, by creating learning communities that emphasize the lifelong skills and knowledge necessary to continue learning, communicate clearly, solve problems, use information and technology effectively, enjoy productive employment, appreciate aesthetics, and meet their obligations as citizens in a democracy."

Based on this mission, the State Board of Education supports local efforts to forge learning communities for elementary and secondary education based upon five fundamental Standards of Expectation for Learning:

- All students can learn.
- Every learner possesses multiple intelligences.
- Participation in a learning community fosters growth.
- Diverse instructional strategies and environments increase learning.
- Learning is a lifelong endeavor.

Philosophy

LEARNING TO LEARN. Education should provide all students opportunities to develop the capacity to renew and extend their understandings throughout life. Present and future demands on this capacity continually arise from technological, cultural, and economic changes in society. Owing to the dynamic interaction between science, technology, and society, some of these changes result from and lead to scientific advances in peoples' understanding of the natural world.

Through an array of experiences, including scientific explorations of the world, learners become conversant with a broad range of subject matter. Through these experiences, learners will become prepared to: 1) identify problems and sort out issues that can be addressed scientifically; 2) recognize and synthesize scientific knowledge and processes; 3) develop scientific skills pertinent to solving problems and resolving issues; and 4) solve problems and make informed, evidence-based decisions in a wide variety of contexts. In short, learners' ability to utilize information and other resources, perform effectively in their careers, and benefit from further education depends on the continuing development of scientific literacy over the entire course of a person's life.

Scientific literacy includes no less than:

- competence in scientific inquiry;
- a sense of wonder about the natural world;
- understandings of humans, other constituent parts of the universe, and their interactions and transformations;
- facility for synthesizing and applying the big ideas of science for the purpose of problem-solving and evidence-based decision-making; and
- a functioning perspective of the interrelations between and among the scientific endeavor, society, and technology.

Science for All Americans emphasizes the need for scientific literacy in the design of a science program by defining a scientifically literate person as: "...one who is aware that science and technology are [interrelated] human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes." (1990: ix)

Scientific literacy continuously develops when the science education program incorporates a wide variety of learning episodes which clearly emphasize:

- learning from concrete to abstract and from familiar to unfamiliar;
- learning from the local setting to the global setting;
- real world doing (hands-on, minds-on);
- cooperative and individual performance;
- learner self-evaluation and curriculum-embedded assessment;
- developmental appropriateness of process and content;
- cooperative planning by learners and leaders;
- interdisciplinary connections;
- risk-benefit analysis;
- moving towards independence; and
- responsible decision-making in real-world contexts.

A science education program enriching enough to facilitate continuous development of scientific literacy will require powerful learning episodes that are relevant and engaging to all learners.

DEFINITION. School science should reflect the definition of science as established by the United States government and the National Academy of Sciences. According to the Federal Court:

> "the essential characteristics of science are:
>
> 1. It is guided by natural law;
> 2. It has to be explanatory by reference to natural law;
> 3. It is testable against the empirical world;
> 4. Its conclusions are tentative, i.e., are not necessarily the final word; and
> 5. It is falsifiable."

(McClean v. Arkansas, 1982, p. 22; upheld in Edwards v. Aguillard, U.S. Supreme Court, 1987)

According to the National Academy of Sciences:

> "In science, everything we observe, measure, or discover must be successfully tested again and again before it is accepted as valid and as factual evidence of what is real. During the application of this scientific method, scientists review their data carefully–and with a healthy skepticism. Most important, the scientific method requires that fact-seekers remain open-minded, are willing to submit their theories to rational examination, and are willing to accept changes indicated by the signposts of evidence. It is easy to see how this approach encourages the acceptance of change, which in turn fosters thought, new ideas, and new hypotheses, all converging on a better understanding of nature."

(National Academy of Sciences, 1984, p. 5)

SCIENCE AS AN ENDEAVOR. Science is one of many ways people explore and understand the natural world. Throughout human history, people from many cultures and educational backgrounds, working individually and collaboratively have participated in this endeavor in many different settings.

The ability of humans to explore and understand the natural world through science is predicated on the predictive power of science, embodied in the durability and reliability of its methods and powerfully elegant ideas. These methods and ideas have enabled humanity to make significant discoveries and build a comprehensive understanding of themselves, other constituent parts of the universe, and their interactions and transformations.

Human explorations of the natural world have also enabled people to invent, adapt, and use technologies to enrich their lives, extend their life spans, and manage their lives under a wide diversity of ever-changing conditions. Human history has been punctuated by unprecedented advances in science and technology. A continuing assessment of the interrelationships among these advances, the needs of society, and the sustainability of our planet is an imperative that must be adequately addressed.

Making discoveries and building understandings of the natural world through the scientific endeavor rely upon making observations, drawing inferences, and exploring testable hypotheses. The target of scientific activity is, therefore, the development of operational understandings of how the world works. Some of these understandings are considered tentative while others exhibit durability in relation to observable evidence and confirmable predictions. This durability does not imply a causal relationship between the theories, hypotheses, and facts of science and the nature or working of the components of the universe, e.g., the theory of gravity does not cause, but it can supplement a description of a falling object. Rather, its utility can be found in its predictive and descriptive capabilities, e.g., the significance of the finite speed of light as a durable, measurable fact is the role it plays in comprehensive, powerful, yet tentative theories for predicting and exploring the characteristics of matter, energy, time, and space.

HOW STUDENTS LEARN SCIENCE . Students come to new learning situations with their own knowledge, learning styles, perspectives, and predispositions. These pre-existing conditions are then challenged, modified, and reconstructed based on new experiences. This *Model Competency-Based Science Program* is based on this philosophy and it will be the basis for the local development of an articulated comprehensive set of engaging and challenging science activities which will consistently and incrementally develop powerful scientific literacy. This science Model shares its philosophy of learning with major national curriculum projects including Project 2061, the Scope, Sequence and Coordination project, and the National Committee on Science Education Standards and Assessment.

SCIENCE AS A WAY OF KNOWING. The construction, renewal, affirmation and extension of operational understandings are the very essence of science as a way of knowing. Science should **not** be taught dogmatically, because dogmas are beliefs and ideas that cannot be tested and refuted. Though some of the knowledge generated by the scientific endeavor is difficult to test or refute, all scientific knowledge can nevertheless be tested and, if the weight of repeatedly observed evidence is overwhelmingly contrary, refuted.

Advances in the scientific view of the world are dependent on the durability of scientific ideas and theories, and the expansion of their reliability. According to the California Science Framework (1990), "Scientific theories are constantly subject to testing, modification, and refutation as new evidence and new ideas emerge. Because scientific theories have predictive capabilities, they essentially guide further investigations."

All student questions in science class should be treated scientifically and with respect by other learners and leaders. Questions that cannot be investigated scientifically should be directed to authorities familiar with the contexts of these questions (e.g. philosophers, family members, guardians, and clergy).

OPPORTUNITY TO LEARN. Science learning can only occur when teachers have enabling resources — adequate materials, continuous professional development, and time to implement the teaching of science as described in this Model. Learning communities do not develop without effort. For teachers to facilitate students' learning, they must serve as role models. This means that teachers need to be confident using science processes and content so they are able to provide activities and experiences that promote student interest. To reach this stage of professional development, teachers must be provided with opportunities to update their knowledge of science and instructional methods and techniques. Technology is playing an ever-increasing role in daily life. Its influence should be reflected in schools. Teachers need time to plan as individuals, as members of instructional teams and as a member of a pre K-12 science staff. Time to plan, time to learn, and materials and facilities to support science instruction emphasize the need for adequate resources.

Finally, there must be a commitment to equity. Disparities between districts, schools, and classrooms that affect students' opportunities to learn must be minimized. The elimination of inequities is a critical goal of a competency-based science program in Ohio schools.

Goals

The following Goals are supported by grade-level objectives organized in four strands. School science programs developed with this model will support and enhance the overall school program as exemplified in the expectations for learning as delineated in *Preparing Ohio's Learners for the Twenty-First Century: Pre K - 12 Performance-Based Standards*. These Goals represent the culmination of science experiences and should be used as a filter for the consistency and development of an articulated science program. They do not prescribe specific content, instructional topics or themes, skills, or processes and should not be used as an organizing scheme.

GOAL 1: **THE NATURE OF SCIENCE.** To enable students to understand and engage in scientific inquiry; to develop positive attitudes toward the scientific enterprise; and to make decisions that are evidence-based and reflect a thorough understanding of the interrelationships among science, technology, and society.

As a result of a successful science education, the learner will:

demonstrate curiosity, open-mindedness, skepticism, and ethical behavior while participating in scientific inquiry;

develop and use scientific skills and concepts to explore how the natural world works and to examine and propose solutions for its problems;

formulate questions, hypotheses, and models drawing upon appropriate means, including logic and imagination, and design investigations to test them;

choose and use appropriate means for making observations, gathering evidence, presenting the evidence in appropriate formats, performing analyses, drawing inferences, and formulating conclusions; and use them to initiate additional investigations and applications;

recognize that scientific knowledge is always open to refinement and can never be declared absolutely certain as demonstrated by the capacity and willingness to modify personal insights and understandings in light of additional evidence; and

engage in personal and group decision-making, using risk-benefit analysis, about the use of technology to solve problems of human adaption.

GOAL 2: THE PHYSICAL SETTING. To enable students to describe the relationship between the physical universe and the living environment, and to reflect upon and be able to apply the principles on which the physical universe seems to run.

As a result of a successful science education, the learner will:

investigate and distinguish among the various macro and micro components, of the universe; explain how they relate to one another; and elaborate on how humans have arrived at their understandings of the universe;

explore and explain the fundamental principles governing relationships between and among matter, energy, space, and time;

construct and interpret conceptual, physical, and mathematical models to explain the motions of the earth and the materials and systems that compose it; and

make and act upon evidence-based decisions to ensure a sustainable environment.

GOAL 3: THE LIVING ENVIRONMENT. To enable students to describe the relationship between the structure and functions of organisms, to assess how organisms interact with one another and the physical setting, and to make decisions that ensure a sustainable environment.

As a result of a successful science education, the learner will:

recognize and explain the similarities and differences among organisms in terms of structure, function, and behavior;

investigate and interpret the causes of diversity and similarity among existent and extinct organisms through time;

construct and interpret conceptual, physical, and mathematical models to explain how humans and other species are linked directly or indirectly with each other and in ecosystems;

investigate and explain how the interactions of psychological, biological, physiological, social, and cultural systems affect mental and physical well-being; and

evaluate how societal decisions about science and technology may impact the survival of various species.

GOAL 4: SOCIETAL PERSPECTIVES. To enable students to analyze the interactions of science, technology and society, in the past, present and future.

As a result of a successful science education, the learner will:

recognize and respect that scientific inquiry and knowledge represent the accumulated work, over many centuries, of men and women in every part of the world;

identify and explain the significance of milestones that define the advancement of scientific inquiry and knowledge;

recognize and evaluate the impact of scientific inquiry and knowledge on human culture and how human culture impacts scientific inquiry and knowledge; and

contribute to the discourse relative to the scientific and technological priorities and their relationship to societal issues.

GOAL 5: THEMATIC IDEAS. To enable students to use major scientific ideas to explore phenomena, inform their decisions, resolve issues, and solve problems; and to explain how things work.

As a result of a successful science education, the learner will:

identify and explain systems, e.g. solar systems, ecosystems, organisms, and chemical and physical systems, by noting components and relationships;

use the concept of systems to organize seemingly isolated facts and observations into comprehendible explanations of how things work;

use conceptual, physical, and mathematical models as simplified representations to help explain and explore how things work or might work;

distinguish among and use the simplifying principles and aspects of systems, e.g. stability, equilibrium, conservation, and symmetry, that remain predictably constant to explore phenomena and make decisions;

distinguish among and apply patterns of change, including trends, cycles, evolution, and chaos, to explore phenomena and make decisions; and

recognize and explain the implications of phenomena understood at various levels of complexity and scale.

Advisory Committee
Meeting
National Center for Science
Teaching and Learning
February 4, 1994
Columbus, Ohio

POSTMODERN SCIENCE AND THE RESPONSIBLE CITIZEN IN A KNOWLEDGE-INTENSIVE ERA

Paul DeHart Hurd

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Stanford University, Stanford, California

Pressures for a reform of science education in the United States have been underway since 1970. The purpose of this essay is to provide a rough index of what is being thought and supported in efforts to formulate a modern framework for the teaching of precollege science. While there is a wealth of confusion about new purposes and little consensus, there is general agreement on one goal--the preparation of young people for responsible and effective citizenship in a democratic society.

To achieve this goal will require a break with the traditional ideology of science education. For the past 200 years science education in the United States has been taught in an academic context. Students are expected to learn to "be like a scientist and think like a scientist." In the first chapter of most science textbooks one finds a formula for scientific thinking called the "scientific method" the longest lasting myth in the history of science. To "be like a scientist" students must learn the language scientists use to communicate their research to other scientists. This language consists of the technical terms, formulas and symbols for each discipline based course in which the student is enrolled. In the middle grades and high school courses this vocabulary consists of 2000-5000 new words. These are words students have never seen before, never heard pronounced, and will likely never use in a conversation the rest of their life. To their advantage, they will probably not have to remember them beyond the next test. School science courses are negatively described as "word study," discipline bound, and with their major outcome forgetting. The question most frequently asked by students in science courses is: "What good is all this going to do me?" The most frequent answer is "You will need to know it in the next grade or in college."

The rest of this essay will focus on a national agenda for an education in the sciences that seeks to reestablish its legitimacy in terms of modern dimensions of the sciences, cultural shifts and social changes. Because we lack a clear vision of what an education in science should mean, the reform movement has now been drifting for nearly a quarter of a century.

Beginning in the 1950s, the United States has undergone massive changes which have altered the character of our society, including our demography, life styles, values, family structure, institutions, economy, the nature and ethos of science, and patterns of American life. The totality of these changes has been characterized by Kenneth Boulding (1964), economist and former president of the American Association for the Advancement of Science, as a "cultural mutation," with science and technology as the basis of this great transition. At the same time the disciplines of traditional science have undergone changes greater than at any time in the past 400 years. Gerald Holton, professor of physics at Harvard and MIT and a sociologist of science, refers to the recent changes in science as "revolutionary."

The public became aware of all these changes in the early 1970s when hundreds of books were published authored by sociologists, political scientists, economists, sociologists of science, natural scientists, and a number of educators. Each alerted the public to major changes taking place in our society, economy, science and technology. The tone of these writings was that schooling in America is on a collision course with our changing culture and the nation's future. The question was raised as to whether schools are fulfilling their obligations to society. What all this means for education in general and science teaching in particular was brought to a focus in 1983 with the publication of A Nation at Risk: The Imperative for Educational Reform, authored by the National Commission on Excellence in Education and released by the U.S. Department of Education.

Since 1970 over 400 other national reports on the need for educational changes have been developed by panels, commissions, and committees, including the U.S. Congress, executive branches of the federal government, special issues from the public press, professional societies of science and education, state governors, school boards, chambers of commerce, presidents of the U.S., commercial educational consulting firms and business and industry. Each report represents what some citizen group believes should be new purposes for schooling in the U.S. A majority of the reports target science education as requiring the most reform. The public keeps asking: Where is the science curriculum that is likely to help young people navigate their way in this new world of ours, a world increasingly distinguished and propelled by achievements in science and technology? Where is the science curriculum with a focus on responsible and effective citizenship and an understanding of the dynamics of science and technology in the nation's social, political, and economic life? A criticism of the traditional science curriculums is that they result in students graduating from high school as foreigners in their own culture unfamiliar with the influence of science/technology on public policy, human values, the future of our democracy and how young people can best cope in this new age that is upon us; and it is "getting newer every day."

What is causing all this educational tension, turmoil, and confusion? There are a number of factors but we can consider only a few within the time available. One is the nation's shift from an industrial age to a knowledge-intensive era. A second is characterized by changes taking place in the nature and practice of the natural sciences. A third factor is related to recent findings in the cognitive sciences and their meaning for learning along with implications for instruction and curriculum frameworks. At the onset it should be recognized that such curriculum reform activities as restructuring, revising, reorganizing, gimmicks and other forms of tinkering and rehashing will not do the job.

Various science education associations and committees over the past decade have published long lists of resolutions, position statements, or recommendations for changes in science education. In many instances these statements are worthy, but lacking is a coherent vision of science education for the 21st century, an era unlike any other in our history. A vision is what ties the whole field of science education together and provides direction for meeting changes.

For the rest of this talk I will focus on some of the insights that have emerged from the writings over the past 20 years concerning what a modern education in the sciences should be. One important issue is the nature and ethos of postmodern science in contrast with the 200-year traditional notions that now dominate science curriculums at all school levels and 99 percent of the textbooks. Curiously, writings on the reform of science teaching say very little about the nature and ethos of the natural sciences as they are today.

Since the turn of this century the traditional disciplines known as biology, chemistry, earth science and physics have each been fractionated into thousands of research fields. This condition of specialization was forced on research scientists if they were to have a chance of making a significant contribution. Each field has its own language, procedures and theoretical framework. Research findings from these new fields are now reported in over 70,000 journals, 29,000 new since 1970, and 20,000 in the biological fields alone. To distinguish the science of today from that of the past, a new name is being sought. Currently the most commonly used names are postmodern science, technoscience, and trans-science. I shall be using postmodern to identify the science we know today.

Traditional science disciplines have become hybridized into new fields such as, astrophysics, biophysics, genetic engineering, laser chemistry, geophysics, biogeochemistry, bioinorganic chemistry, biotechnology, molecular biology and hundreds more. Ethnoscience, sociology of science/technology, and the symbiotic relationship of postmodern science and economics represent cross-disciplinary perspectives of the natural and social sciences. In postmodern science new research is concentrated in the biological fields; traditionally it has been in the physical sciences. For example, of the ten most widely cited research papers in 1992, nine were in biological sciences and one in chemistry. A century ago it was the physical sciences that moved this nation from an agrarian to an industrial society. Today ongoing research in biotechnology is viewed as the most likely forerunner of a new industrial revolution in the 21st century.

The integration of science and technology provides yet another way that distinguishes today's science from the traditional. The distinction is best seen in the ways computer technology influences research. Computers extend human capacities for observation, such as the scanning tunnelling microscope that makes it possible to see chemical bonds in living cells. In 1992 a micro-laser was developed that makes it possible to break these bonds one at a time.

The title of the article reporting this achievement was "For the first time it is now possible for chemists to see chemistry in action." Another example is the Hubble space telescope that is reporting observations in space which will likely increase our knowledge of astronomy by some 80 percent in the near years. It has already extended the limits of outer space to the degree that makes the use of light years seem too small a unit for measuring cosmic distances.

Computer simulations provide ways to carry out experiments that have heretofore been considered impossible. An American Association for the Advancement of Science symposium viewed computers as the "third branch of science." In postmodern scientific research, science and technology are seen as phases of a cognitive system for the production of new knowledge, not as separate entities. Computers are essential members of research teams. They summarize in a few minutes what is known or not known about a problem, prepare models derived from data, and continuously organize data from other research teams, sometimes scattered throughout the world, such as in the study of AIDS.

Nearly all postmodern scientific research is done by teams of researchers working as a unit. The twelve most cited science research papers published in 1991 had an average number of 6.6 authors per paper. A recent issue of <u>Science</u>

carried research reports by author teams of 14, 17, and 27 individuals. The international record is 134 authors in a study of world ecological imbalances.

Postmodern science is more holistic in concept than traditional science. Scientific research today is more socially than theory driven. It operates in a larger context than is found in the traditional discipline-bound sciences. Research teams may be a mix of natural, social and cognitive scientists. This combination of minds serves to increase the fertility of ideas as well as extend the range of research. Studies in biotechnology, human behavior, the neurological basis of human learning, and the genetic treatment of human diseases are examples.

The National Science Foundation, in December, 1992, proposed new standards for the science research it supports. One is "a greater integration of science and engineering research into society, and the public's increasing expectation for the results of this research." Another recommended standard is a priority for the "support for research that crosses traditional boundaries and links science and technology." The current (1993) chairman of the House Committee on Science, Space and Technology, of the U.S. Congress is George E. Brown, Jr. who this spring pointed out to Congress that there has been a "paradigm shift" in the sciences that "requires us to reconsider the role of science in our society." (See June 1993 issue of Scientific American, page 152.) This new form of scientific investigation is done in a social, economic, environmental, or human context and is identified as strategic research. This term replaces the traditional notion of applied research. We should also note that today 58 percent of all researchers in the natural sciences are employed in industry, 36 percent in universities.

To be sure, little will be gained if we attempt to invent new science curriculums without regard for the nature and ethos of postmodern science. In addition, there are other issues which must also be considered to achieve a public understanding of science.

1. In a rapidly changing knowledge-intensive society, what it is important to know in a lifetime cannot be taught in 12 to 16 years of schooling. The essential instructional goal has already emerged and defined in terms of "learning to learn." According to UNESCO, of the 141 countries now revising school science curriculums this is the only goal common to all. The skills needed to achieve this goal include knowing sources of reliable information, how to access this knowledge, and how to use knowledge in relevant and rational ways. Associated with this goal is the recognition today that in the sciences all facts, laws, and

and theories are forever tentative, subject to change without notice. The old concept of "basics" as permanent knowledge is now viewed as a myth. The central purpose of this goal is to put students in command of their own intellectual potential.

2. In a world of accelerating changes and for a society that is knowledge-intensive one must become a student for a lifetime. This goal is essential for achieving optimal levels of cultural adaptation and for continual success in the world of work. It is already evident in our economy that when speaking of a "dead-end" job it means a person not a position. The details of this goal are described in a U.S. Department of Labor publication titled Learning a Living.

3. The public is demanding the teaching of higher-order thinking skills in science courses. Currently the emphasis is almost entirely on inquiry and processes representing lower-order thinking skills. These are skills having to do with how science information is generated, classified, expressed and interpreted. These skills are for the most part quantitative in nature and discipline bound.

The appeal for higher-order thinking skills is related to the proper use of science/technology knowledge in human and social affairs. These skills are characteristically qualitative. When science/technology information is brought into contexts where it serves people and society, elements of ethics, values, morals, bias, politics, risks, ideals, trade-offs, and aspects of probability enter the thinking process.

These intellectual attributes are essential for understanding the interactions of science and technology as they influence human experience, the quality of life, and social progress. In addition, to deal with science/ technology concepts in the context of responsible citizenship requires that the learner be able to distinguish science from pseudo-science, theory from dogma and the practical, fact from myth or folklore, probabilities from certainty, data from assertions, and reasonable from the unreasonable. In addition, students will need to understand the limitations of scientific inquiry, and to recognize modes of thought common in the natural sciences as well as those of the social sciences and the humanities.

4. A new context for curriculums in the sciences is one that considers the unknown future. This is not in the sense of predicting the future but to enable young people to make choices in planning the society and their own lives for living, learning and working in the world in which they will be spending their lives. Traditionally school science courses have been historically oriented. The history of science is not to be ignored but made richer by pointing

out what we used to believe, what we believe now, and what we wish we understood. How else can we convey the changing nature of science/technology and put stars in the eyes of young people for choosing careers in science or technology?

5. To match the nature of postmodern or technoscience with its emphasis on strategic research designed from the onset to benefit human well-being and social progress, the new view of the school science curriculums has the same purposes. This trend is generally described as relating science to the real-life and real-world of the student. In this context the student is the curriculum. A first step in developing this new science curriculum is to identify the personal, social and behavioral needs of students at various developmental levels to serve as the curriculum framework, blueprint, or the basis for standards. The educational rationale is a science curriculum that can be lived and that benefits the individual, the quality of life, and the common good. These perspectives are in contrast to the traditional notion that the reform of science education is just a matter of identifying the current structual concepts and theories of the traditional academic science disciplines. What is sought is a curriculum that can be experienced by students.

6. Over the past two decades cognitive scientists have been researching factors related to how people learn, remember and use knowledge. First we should recognize that science information becomes knowledge only in our ability to use it. If a student knew only every fact, law, symbol and theory of science he/she could only be identified as ignorant. It has also become evident that students engaged in traditional laboratory or "hand-on" activities are limited in their learning by what they have been prepared to observe. They learn more from investigations when they are a part of the action, not that of a routine "performer" of an experiment. To activate these purposes will require a new cognitive framework for the teaching of science.

7. To place science education in a socioculture context with a focus on effective citizen participation in a democracy compels an interdisciplinary core curriculum. Concepts from the wealth of science fields will need to be brought together and unified in terms of personal development, quality of life, human affairs and social progress. Resolutions for these issues do not lie solely within the natural sciences but have connections with the social sciences and humanities. These connections will need to be developed as part of the core science curriculum in cooperation with other school subjects, including mathematics.

In summary it should be noted that there are other aspects in the task to modernize precollege education in the sciences. I have outlined only some of the major components inherent in the shift of our society from an industrial to a knowledge-intensive era, propelled by advancements in science and technology. Education in the sciences now takes on the nature of enculturation. A broader, more holistic perspective for science teaching is being sought, one in which the subject matter and conceptual themes connect postmodern fields of science with the learner, human affairs, and social progress. Such a curriculum will of necessity blur the present distinctions between schooling and the real-world, as well as between science and technology. The over-arching goal is a curriculum focused on responsible citizenship, enabling young people to live wisely and actively participate in our emerging knowledge-intensive science/technology culture. Major actors in this reform movement are research scientists as the creators of knowledge; teachers as the interpreters of science/technology in the context of human affairs; and students as users of science knowledge for making personal and social decisions.

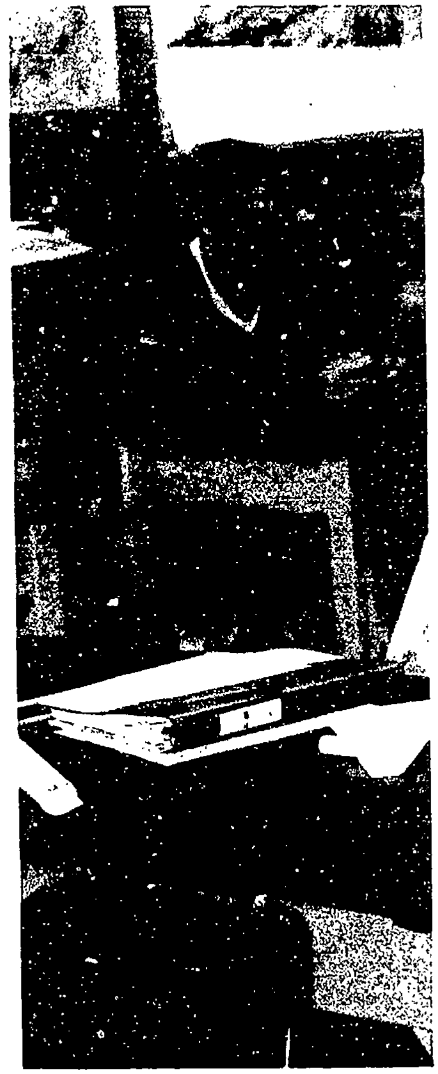
What I have portrayed in this essay is not new. Francis Bacon in 1620 wrote "... the ideal of human service is the ultimate goal of scientific effort ... providing a better and more perfect use of human reason." To achieve this goal, Bacon recommended a selection of "... subject matter which does the most for the welfare of man." He also noted that "the true ends of knowledge" are in its "benefits and use in life."

Note

Aspects of this talk were previously presented in papers prepared for the Chicago Academy of Sciences (October, 1993) and the National Academy of Sciences (December, 1993).

Biological & Earth Systems Science

A program for the future



The present curricula in science and mathematics are overstuffed and undernourished.... To turn this situation around will take determination, resources, and time.
—AAAS, Project 2061: Science for All Americans

by Rosanne Fortner, Roger Pinnicks, Edwin Shay, Pat Barron, Dan Jax, William Steele, and Vic Mayer

As far back as 1987, the high school science teachers of Worthington, Ohio, began to sense a need for change. Their dissatisfaction with the current curriculum grew as reports continued to rank U.S. students at the bottom of the global scale for achievement in Earth science and advanced biology. Only 3 percent of high school students enroll in Earth science; biology is the preferred starting course. And, as Project 2061 began to call for a "less is more" approach to science teaching, they were encumbered with a 1.35 kg Earth science text with a 550-word glossary and an even larger 1.5 kg biology text with a 900-word glossary. A system-wide self-assessment also identified other problems that included a lack of computer literacy, technology access, real world linkages, and science career guidance. The impetus for change was in place.

TO TURN THIS SITUATION AROUND...

In response to the situation in their district, 10 science teachers, the department chair, and another teacher on special assignment collaborated to restructure the secondary science program. They sought to refocus lesson plans in the natural sciences, so that students would once again be learning about the structure and function of Earth systems—a focus all but abandoned in many secondary school programs.

WILL TAKE DETERMINATION,...

The efforts of the Worthington team were bolstered by statements of professionals on all levels. Project 2061 helped by identifying what every high school students should know. NSTA's Scope, Sequence, and Coordination echoed the need for change. At a conference sponsored by NSTA and the American Geological Institute, geoscientists, teachers, and science educators discussed the need for Earth science literacy. Ed Shay, a member of the Worthington team, participated in that meeting and came away feeling that the answer to his district's problems with ninth grade science was at hand.

The Worthington group refined a vision of Earth Systems Education that focused on how the subsystems of hydrosphere, atmosphere, lithosphere, biosphere, and cryosphere interact and relate to human activities. As a national curriculum model, Earth Systems Education provided a relevant context for teenagers.

Bringing about changes in curriculum structure, however, is not something to be taken lightly. Years of experience with the same curriculum generate a degree of comfort and confidence in teachers. To convince teachers to abandon their ways and strike out into the unknown is not a task for the faint of heart.

The Worthington team embraced the need to restructure, and vowed to make change happen. The course they designed

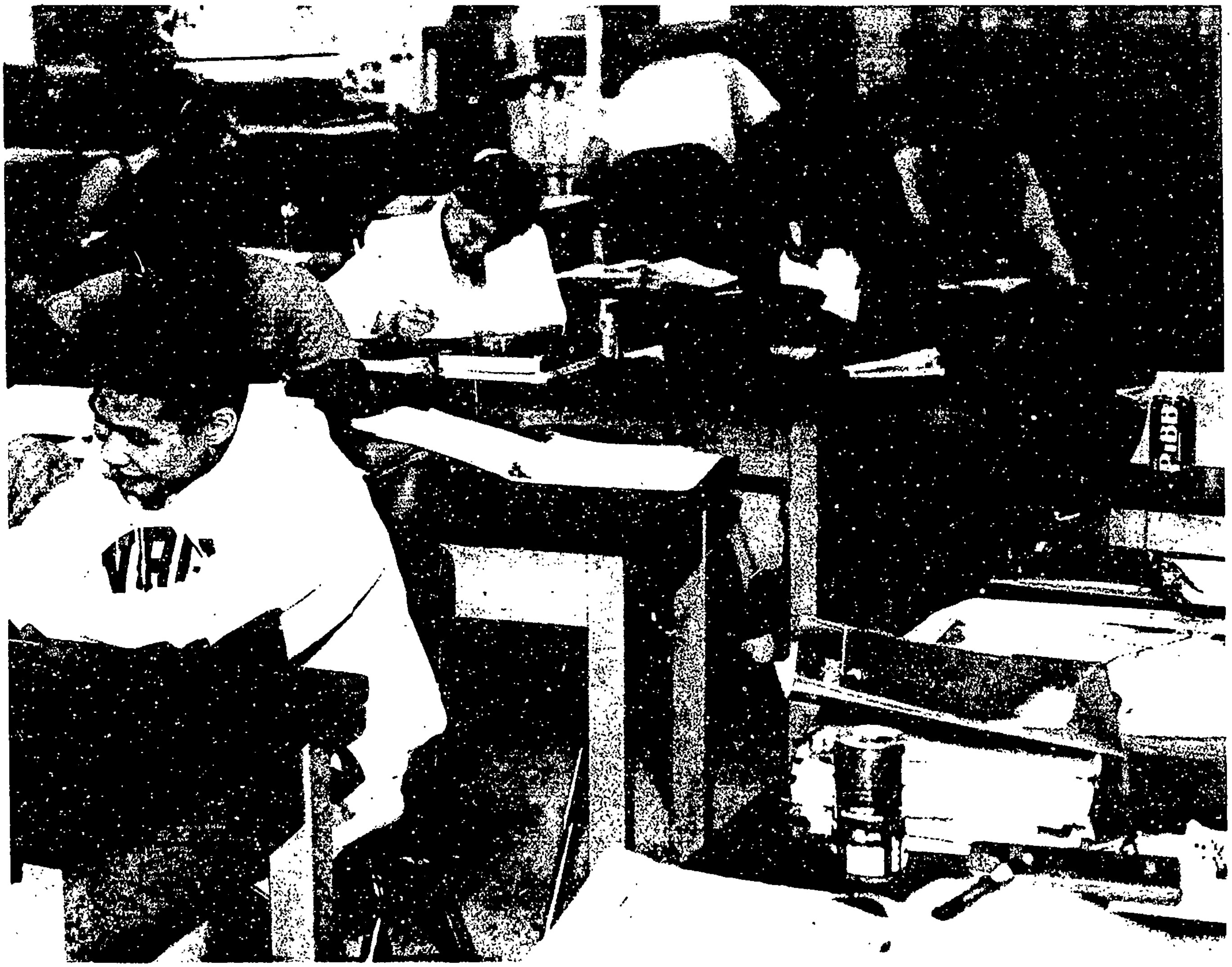


PHOTO BY BRENDA HAMILTON

integrated the ninth and tenth grade program into a new curriculum, Biological and Earth Systems Science (BESS), which offered:

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

The team was so committed to their product that they encouraged the administration to make the new two-year sequence a *requirement* for all students. BESS I was taught in 1990–91, and BESS II for the first time in 1991–92. (The learner outcomes of the course are listed in Figure 1.)

RESOURCES,...

To start up a new program such as BESS, the team needed money, equipment, materials, and most of all, time. Once the weighty textbooks were abandoned, teachers had to find appropriate reading and lab materials. A new mindset had to be adopted, as well, as the boundaries between traditional subject matter and categories were softened and connections were emphasized.

The staff worked with the Ohio State University faculty in seeking out grants and materials for the BESS program. To broaden their own horizons, individual BESS teachers participated in the JEdi development project, the Sea Education Association Satellites in Education Conference, a conference on alternative assessment methods, and NSTA, NABT, and GSA conventions. The most valuable resource, however, was the creativity and resourcefulness of the teachers and their advisory groups.

LEADERSHIP,...

Little of the progress in BESS to date would have been possible without the commitment of those on the front lines of reform, the teachers themselves. They had a sense of mission, and theirs was truly a cooperative learning experience. A national advisory board was chaired by teacher Dan Jax from a nearby school system. Stanford professor Paul DeHart Hurd brought a national perspective, and provided the leadership that was needed when opposition surfaced. Some of the key objections raised by the "status quo" included:

- parents of talented students who wanted a one-year fast track to A.P. courses.
- Guidance counselors and parents, who feared that the course name on a transcript would be misunderstood by colleges. (The term Biological was added to the course name as a result of counselor input.)

It is fortunate that the many types of

FIGURE 1. Learner outcomes.

As a caring, responsible, and scientifically literate person, I can...

1. Exhibit a holistic understanding of planet Earth, recognizing that it is a system comprised of changing and interacting subsystems.
2. Demonstrate an aesthetic appreciation of, and respect for, the beauty and value of the Earth, its grand cycles, and its life.
3. Exhibit a holistic understanding of individual organisms, recognizing that each is a system comprised of changing and interacting subsystems, and that each is also a part of environmental processes.
4. Demonstrate an awareness that humans are unique, that our activities may seriously impact planet Earth, and that individually and collectively we have the responsibility to make informed decisions on issues affecting the future of our planet and its inhabitants.
5. Demonstrate wise use of Earth's limited resources.
6. Use current technologies (computers, remote sensing, laboratory instrumentation, etc.) as tools to access and process information.
7. Access, sort, interpret, analyze, evaluate, and apply information from a wide variety of sources, both current and historic.
8. Recognize and define problems and issues, and demonstrate skills useful in solving problems and analyzing issues.
9. Demonstrate skills for engaging in individual and collaborative scientific and social endeavors.
10. Demonstrate effective communication skills within the context of science.
11. Show understanding of the basic concepts and principles of science, and apply them (along with the processes of science and technology), to solve problems, make decisions, and understand the world.
12. Recognize biased information, pseudoscience, and fact versus opinion.
13. Take and justify positions on science-related issues, based on valid, rational science concepts and ethical values.
14. Demonstrate an awareness and appreciation of the personal usefulness of science as a way of learning about how the world works.
15. Demonstrate awareness of science-related skills, careers, and avocations.

leaders in the program maintained the determination to make it work.

...AND TIME.

More time than anyone could have imagined was spent developing curriculum while curriculum was in progress, planning day-by-day, securing materials and assistance. Physics teacher Faulke Palmer served as director managing fiscal aspects; Ed Shay and biology teacher Roger Pinnicks developed the broad master strokes on integrative topics, and special assignment teacher Pat Barron facilitated the process. Pinnicks and Jim Immelt were released from all teaching for the critical second year of planning, facing not only a new curriculum but a new set of parents and a new superintendent. No one said it would be easy, but all are convinced it is worth the effort.

Program evaluation is in progress to gauge the success of the BESS program in meeting its goals. Like all other aspects of the effort, this is a multifaceted challenge. The current instruments used to identify merit scholars are not likely to be the same ones that can assess collaborative skills, choice of technological applications, thinking and application ability, and knowledge of information resources, not to mention critical consumption of science information and recognition of the limitations of science.

For now, several forms of evaluation are in progress, assessing BESS students' performance in achieving the major goals of the course as well as mastering worthy portions of the more traditional science content. In general, student attitudes toward their science experiences are very positive in comparison with those in traditional courses prior to BESS and in other schools. The academically talented students have difficulty with the new operating modes and evaluation methods that do not rely on traditional testing. This portends a challenge for all curriculum restructure efforts. As Paul Hurd has said, "Everyone is in favor of progress but no one wants to change!" As we look harder at what real learning consists of, we must look equally hard at how to measure successful teaching. The ultimate goals of BESS are expressed as learner outcomes that transcend science disciplinary goals, and as evaluation of the program proceeds, the richness of data measuring those outcomes will add new dimensions to our understanding of success in science teaching and learning.

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NOTE

For additional information on BESS, please contact Rosanne Fortner at the address provided or BESS program leader Brian Luthy at Thomas Worthington High School, Worthington, OH 43085.

FIGURE 2. Year one framework.

A. WHAT IS A SPECIES?

Topic: Species and Populations

A1. What is a species?
A2. How and why do scientists classify things?
A3. What is species diversity and why is it important?
A4. How are changes in populations caused by nature?
A5. How do humans bring about population changes in other organisms?
A6. How is it possible that you can influence the possible extinction of species, including humans?
A7. What are the consequences of continued population growth?

B. WHERE IN THE WORLD ARE WE?

Topic: Change and Remote Sensing

B1. How are maps, aerial photos, and satellite images used to study the Worthington area?
B2. How do comparisons of data/information over time show change?
B3. How do ground observations provide clues for the interpretation of aeria' photos and satellite images?

C. WHAT CAUSES WEATHER CHANGES?

Topic: Weather Systems

C1. What is the source of energy in our atmosphere?
C2. What causes weather to change?
C3. What are the interactions between large bodies of water, land, and atmosphere that influence weather?
C4. What makes the wind?
C5. What makes it rain or snow?
C6. How can changes in the weather be monitored and predicted?
C7. What causes seasonal changes in the weather?
C8. How does weather affect you, and how does it affect other organisms?
C9. What causes violent weather such as blizzards, tornados, thunderstorms, and hurricanes?
C10. How can you protect yourself in a blizzard, a tornado, or a thunderstorm?

D. WHAT FACTORS INFLUENCE ECOSYSTEMS?

Topic: Ecosystems

D1. How did the landforms and soils in this area develop?
D2. How did the bodies of water and landforms influence organism distribution?
D3. How do we make use of these natural features today?
D4. How does energy flow within an ecosystem?
D5. What are some interrelationships in an ecosystem?
D6. How are ecosystem relationships altered and what are some of the results of these changes?
D7. What are the factors that make up our deciduous forest biome?
D8. What factors could alter our deciduous forest biome?
D9. What are the factors that make terrestrial and aquatic biomes in the world unique?
D10. What effects do biomes have on global environments?

E. HOW IS AN INDIVIDUAL ORGANISM A PRODUCT OF ITS ENVIRONMENT?

Topic: The Individual Organism and Its Environment

E1. How is structure related to function in complex organisms?
E2. How does design (structure) influence the way organisms behave?
E3. How does the environment help to influence the design and/or behavior of an organism?
E4. What are some of the positive and negative ways that organisms respond externally to factors in their environment?
E5. How is an individual organism a product of what it takes in?

F. WHAT ARE THE LOCAL AND REGIONAL NATURAL RESOURCES THAT WE USE, AND HOW DOES THEIR USE IMPACT THE EARTH SYSTEM?

Topic: Ohio's Natural Resources

F1. What are Ohio's major natural resources, how did they form, and how do we use them?
F2. Which of these Ohio natural resources are renewable? Which are non-renewable?
F3. What are some of the consequences of obtaining and/or using these resources?
F4. How can we minimize the effects of the resulting wastes on the environment?

G. CULMINATING ACTIVITY

FIGURE 3. Year two framework.

H. WHAT IS A SYSTEM? A SUBSYSTEM?
Topic: Systems Concept (revisited)

I. HOW DO INDIVIDUAL ORGANISMS FUNCTION AND CHANGE THROUGH TIME?
Topic: Organisms as Systems: Structure and Function of Individual Organisms

I1. What is the internal structural organization of organisms?
I2. How do the internal subsystems of an organism function and respond to change?
I3. What are the main biochemical processes that sustain organisms?
I4. What structures and biochemical processes are related to reproduction?
I5. How do the structures and biochemical processes of organisms function interconnectedly to achieve essential matter and energy exchanges?
I6. What are some of factors that may change the normal functions of an organism's subsystems?
I7. What are some issues or concerns regarding the well-being of individual organisms?
I8. What makes life unique, valuable, and beautiful?

J. HOW AND WHY DO THE EARTH'S SUBSYSTEMS CHANGE AND INTERACT THROUGH TIME?
Topics: Changes and Interactions: Crustal/Ocean Evolution, Ecological Succession, and Climate Change

J1. What are the causes and effects of crustal evolution and other major changes in the Earth's subsystems?
J2. How does matter move through biogeochemical cycles involving different subsystems?
J3. What can fossils and other Earth archives tell us about the nature of and the rate of changes and interaction in the Earth's subsystems?
J4. How can changes in the Earth's subsystems be monitored and predicted?
J5. How and why are humans altering the Earth's subsystems?
J6. What are some issues or concerns raised from these activities?
J7. What should we do to minimize our negative impacts or changes in the Earth's subsystems?

K. HOW AND WHY DO SPECIES CHANGE THROUGH TIME?
Topics: Organic Evolution, Reproduction, Genetics, and Biotechnology

K1. How do the major natural processes that may result in changes in species work?
K2. What changes in genetic diversity may result from these processes?
K3. What evidence is there for organic evolution?
K4. How are genetic information molecules replicated, transmitted, expressed, and altered?
K5. What are the mechanisms and principles of genetics/heredity?
K6. How and why are humans altering natural genetic and/or reproductive processes?
K7. What are some potential implications and impacts of these alterations?
K8. What are some issues or concerns raised by these alterations?

L. HOW SHOULD WE MANAGE EARTH'S LIMITED NATURAL RESOURCES AND REDUCE NEGATIVE IMPACTS ON GLOBAL ENVIRONMENTS?
Topic: Earth's Limited Natural Resources

L1. What and where are Earth's limited natural resources, how were they formed, and why are they important?
L2. What are some issues or concerns regarding Earth's natural resources?
L3. What is the relationship between human population growth and the implications of managing Earth's natural resources?
L4. What are the responsibilities of humans toward natural resources?
L5. How can/should renewable resources be managed for sustainability?
L6. What are some organizations that are involved in environmental stewardship activities?
L7. What are some options available in the acquisition and utilization of natural resources that would minimize negative impacts on Earth's subsystems?

M. HOW SHOULD WE MANAGE WASTES AND POLLUTANTS AND REDUCE NEGATIVE IMPACTS ON GLOBAL ENVIRONMENTS?
Topic: Wastes and Pollutants

M1. Which major pollutant sources are not the result of human activities, and cannot or should not be managed?
M2. What are some issues or concerns regarding wastes and pollutants?
M3. How can wastes and pollutants that enter one Earth subsystem affect other Earth subsystems?
M4. What is the relationship between human population growth and the magnitude of waste and pollutant problems?
M5. How should we manage human-activities-generated wastes and pollutants and reduce negative impact on global environments?

N. CULMINATING ACTIVITY

INSIDE A BESS CLASSROOM

If you were to walk into a BESS classroom, how would this integrated program be different from a typical high school biology or Earth science class?

FACILITIES

Teacher Brian Luthy's room is typical of a BESS classroom. Its walls are covered with student generated computer art and collages illustrating interrelationships between various science topics. There are terraria and aquaria, rocks and minerals, and many maps and aerial photos in different formats on display. A magazine rack holds a variety of current science magazines. The classroom also contains six Macintoshes with large color monitors. One Mac has a modem attached to the phone line in the preparation room, and another is linked temporarily to the videodisc player. An IBM and CD-ROM workstation is carted between rooms as needed.

SCHEDULE

The class period is 55 minutes long, and BESS teachers have five classes per day. Teachers share a release day once a month, during which they exchange ideas and activities. Since computer hardware is somewhat limited, teachers alternate activities within the scope of a single science investigation. For instance, while one teacher has the computers for simulations or database development, another teacher does field work or uses mapping exercises to complement the computer applications.

SYLLABUS

The framework for BESS I and II is based on questions to be explored (see inset). It is a fluid structure for the curriculum, capable of being rearranged or otherwise altered in response to external events (teachable moments that can not be ignored, or internal opportunities such as teacher expertise and student interest).

A look at the types of questions used to structure the BESS curriculum makes it clear that this is not simply a course that does Earth science today and biology tomorrow. Topics suggested by the questions are integrated to a far greater extent, and frequently involve the use of innovative data sources. The questions are designed to address components of the Framework for Earth Systems Education (Figure 3), a way of thinking about science content that can quickly demonstrate the idea that "less is more." To fully develop one of the Earth systems understandings takes thought, innovation, use of diverse forms of historical and experimental data, and interaction of people with different approaches to problem-solving. Not only the content of the course, but the methods are different.

TEACHING METHODS

Lectures are rare, but 10-minute orientation programs may be used to introduce a new topic or laboratory approach. Visual aids come from videodiscs and CDs, and reading materials are drawn from daily newspapers and other periodicals. The main purpose in "teaching" is to set up a scenario for an investigation or establish a collaborative learning framework for a new topic.

Students work as teams about 75 percent of the time, alternately learning material from up-to-date sources and teaching it to other groups by integrating it with information they have collected. Serious discussions of science process, data interpretation, social ramifications of science, and so forth, are carried on in groups and may be brought to the entire class for amplification.

GRADING

Students are learning in nontraditional modes, and performance evaluation is adapted to those modes. Group activities are judged on the basis of a grading rubric that incorporates the objectives for the study as well as group process skills. Authentic assessments provide scenarios that require students to apply knowledge to new situations. For example, what must be known, and how can the information be obtained, to decide whether an extirpated species (river otters) could be successfully reintroduced to the local environment? Given certain data about river otter natural history and local development, students predict the outcome of reintroductions at various sites along the river.

SOME SPECIFIC EXAMPLES OF BESS ACTIVITIES

Endangered and threatened species are just a part of the important topic of biological diversity and its importance for a shared planet. Instead of doing encyclopedia research on various species, cooperative groups selected species to study for the purpose of protecting them. Their task was to find current relevant information on their species and threats to its survival, and present a proposal for how a grant of $5 million could be used in species preservation.

SimCity, a Maxis software program, is used extensively in BESS I for its capability to simulate land use planning and evaluation of alternatives in municipal development. When student groups are familiar with the way the simulation operates, they are challenged to develop the most polluted city possible. Since they know what combinations of housing, commercial, and industrial development create problems for the Sims, they can easily maximize the problems. The next challenge is to take a given amount of city funds and develop programs that rescue SimCity and restore ecological and social tranquility to their representative Earth systems.

Students at one high school studied a river that flows near their school. Collecting data from the river and its banks, using published scientific literature, aerial photos, and topographic maps, they assessed the feasibility of reintroducing the river otter to the area. Students then had to make recommendations to the head of the Ohio Department of Natural Resources on whether to reintroduce the otter or not.

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