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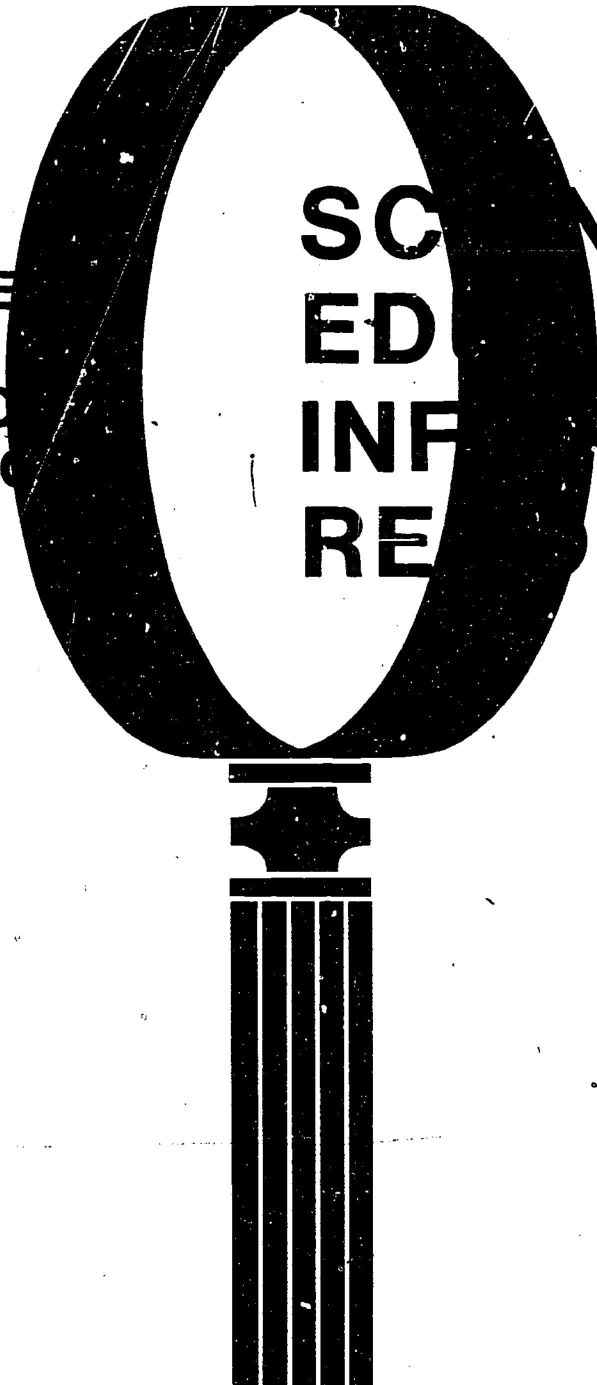
ABSTRACT

Presented in this document are the results of the five focus groups involved in Project Synthesis, a research study designed to synthesize and interpret the information found in the three National Science Foundation-funded status studies (the literature review, the national survey, and the case studies "The Status of Pre-College Science, Mathematics, and Social Studies Educational Practices in U.S. Schools: An Overview and Summaries of Three Studies," ED 166 034); reports from the science assessment efforts of the National Assessment of Educational Progress; and an analysis of current science textbooks as well as some other analyses of the current situation in K-12 science. Using a discrepancy model, the focus groups (biological sciences, physical sciences, inquiry, elementary school science, science-technology and society) each set forth a desired state, described the actual state of affairs in science education, identified discrepancies between the desired state and the actual state, and made recommendations for future action. Analyses relate to four student goal clusters. (PB)



SCIENCE EDUCATION INFORMATION REPORT

THE ERIC SCIENCE, MATHEMATICS AND ENVIRONMENTAL EDUCATION CLEARINGHOUSE
in cooperation with
Center for Science and Mathematics Education
The Ohio State University

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ERIC®

Volume 3

What Research Says to the Science Teacher

National Science Teachers Association

in cooperation with

ERIC® Clearinghouse for Science, Mathematics
and Environmental Education
The Ohio State University
College of Education
1200 Chambers Road, Third Floor
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Educational research is sometimes criticized for not being directly applicable to practice. Perhaps one reason for this is the dedication and hard work required to connect research to practice. This volume reflects the hard work of many persons and agencies, and we are deeply grateful to them. They include:

The National Science Foundation, which funded Project Synthesis as well as a large portion of the research on which the project was based. We owe special thanks to Ray Hannapel for his extremely helpful and supportive monitoring of the project and to Alphonse Buccino for his encouragement and words of wisdom;

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Finally, we owe the most to the people in the five focus groups, and to their group leaders who produced the Project Synthesis Report and wrote the chapters in this volume. The names of those 21 people and their affiliations are listed at the front of their respective chapters. This volume is largely a distillation of the judgments of those illustrious people who took valuable time out of busy schedules to be a part of the effort.

Thank You All Very Much. N.H., R.Y.

THE ERIC SYSTEM

ERIC is an acronym for the Educational Resources Information Center, a nationwide information system designed and supported by the National Institute of Education (NIE). ERIC is composed of a nationwide information network for acquiring, selecting, abstracting, indexing, storing, retrieving, and disseminating the most significant and timely education-related reports. It consists of a coordinating staff in Washington, D.C. and 16 Clearinghouses located at universities or with professional organizations across the country. These Clearinghouses, each responsible for a particular educational area, are an integral part of the ERIC system.

Each Clearinghouse provides information which is published in two reference publications, Resources in Education (RIE) and Current Index to Journals in Education (CIJE). These monthly publications provide access to innovative programs and significant efforts in education, both current and historical.

In addition, each Clearinghouse works closely and cooperatively with professional organizations in its educational area to produce materials considered to be of value to educational practitioners.

Clearinghouses of the Educational Resources Information Center (ERIC) are charged with both information gathering and information dissemination. As Rowe pointed out in the introduction to Volume I in this series, there is a need for teachers both to become more aware of relevant research and to participate in research activities.

Awareness must precede action. In an attempt to help teachers develop this awareness of research in science education and of how research can be used to improve teaching-learning, the ERIC Clearinghouse for Science, Mathematics, and Environmental Education has commissioned a third publication focused on research in science education and the implications of this research for classroom practices.

The ERIC Clearinghouse for Science, Mathematics, and Environmental Education has worked cooperatively with the National Science Teachers Association (NSTA) on this publication. The publication is a report of a research project, Project Synthesis, funded by the National Science Foundation. The director of NSTA's Division of Research worked with Norris Harms, director of Project Synthesis, to produce this third Volume of What Research Says... It is hoped that this document will stimulate teachers to become interested and involved in research.

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I. PROLOGUE

Robert E. Yager
University of Iowa

The launching of the Russian Sputnik in 1957 resulted in a wounded national pride which triggered public support for improved science education in the United States. Morris Shamos, physicist, science educator, curriculum director, and past president of NSTA has estimated that five billion dollars were expended during the fifteen years following Sputnik to improve K-12 science education. This massive effort was impressive and compares most favorably with other major undertakings of the American government and our society as a whole.

One part of this effort was the curriculum developmental projects supported by the National Science Foundation and the subsequent preparation of teachers to use the new materials. About seven hundred million dollars was available for curriculum development and teacher education activities. It is important to note retrospectively that the curriculum efforts were largely attempts at reorganizing and updating course content and that the teacher education activities were designed to improve the subject matter competency of teachers.

Two central assumptions, one from the scientific community and one from the learning psychologists, supported the new science education programs of the sixties. These assumptions were:

(1) If science is presented in a way it is known to scientists, it will be inherently interesting to all students.

(2) Any subject can be taught effectively in some intellectually honest form to any child at any stage of development.

These ideas justified the search for unifying schemes, central concepts, major ideas of the various disciplines of science prior to curriculum development. Furthermore, they supported teaching science as inquiry, thereby providing students with experiences with doing science. The resulting efforts, in terms of course content and teaching methodology, were designed to produce superior scientists and engineers as well as to exemplify the ways scientists do research.

More than two decades have passed since the launching of Sputnik. Americans have forgotten the wounded spirit that characterized our nation in 1957. After all, we, too, have conquered space and landed the first man on the moon. We have scientists and engineers at work on many problems. We seem to have succeeded in producing enough talent in terms of both quantity and quality. The 1970's were years of great change and turmoil. The Viet Nam war, environmental degradation, nuclear power, urban problems, depletion of natural resources, international political strife, all combined to cause us to question the scientific community, our educational institutions, our government, many professions, and lastly, our national purpose. These factors also affected, perhaps adversely, science education.

Due to these many factors, science education changed radically in the early 1970's. Funds for the Science Education Directorate of the National Science Foundation were reduced. Gone was the public support for extensive curriculum development and/or for teacher education activities. Several exciting curriculum developments, however, were underway, including Outdoor Biology Instructional Strategies (OBIS), Human Sciences Program (HSP), Unified Science and Mathematics for Elementary Schools (USMES), Individualized Science Instructional Strategies (ISIS) and Technology - People - Environment (TPE).

These programs represented first attempts at curriculum development rather than course improvement. There was a decision to support larger scale and longer termed projects in the area of teacher education; also there was a policy change which targeted funds to projects designed to implement the course improvement programs of the 1960's in the schools.

The changes of the 1970's resulted in major problems with respect to public and Congressional support for science education. Individuals and organizations (many of them fundamentalist groups) attacked some of the old (e.g., MACOS) and most of the new curriculum efforts as "unAmerican", inappropriate, and even pornographic. At the same time publishers and others mounted a major criticism of the type of teacher education activities supported by the federal government. They questioned the ethics and the legality of NSF support of teacher education activities which emphasized use of specific national course improvement programs, all of which were published by private companies. They suggested that the use of public funds for assisting teachers and schools with the use of materials that were distributed by private companies (although they were initially developed with public funds) was inappropriate. These concerns caused a major reassessment of policies, directions and support for science education activities. During the mid-1970's work on curriculum development was curtailed; active projects were scaled down and few new ones were initiated. During 1975-76, teacher education activities were suspended.

In this setting, the National Science Foundation in 1976, in response to Congressional pressure, awarded contracts to assemble information that would provide a picture of K-12 science education. An attempt was to be made to assess the impact of public support for science education during the past twenty years. Were the improved courses and the support for teacher education successful? Had science education kept pace with science, society, knowledge and schooling?

Each of three studies was designed from a different perspective. Helgeson and his colleagues at Ohio State University summarized the published and unpublished literature concerned with science education during the 1957-75 period. The information surveyed centered upon practices in schools, instructional materials, teacher education, administrative/financial control and needs in K-12 science. A second study was headed by Iris Weiss of the Research Triangle Institute. It was a national survey of teachers, administrators, supervisors and other school personnel. Using questionnaires, information was sought concerning curricula, course offerings, teaching methods, enrollments, individualized materials, teaching assignments, support services and demographic information about teaching practices. The third study, conducted by Stake and Easley of the University of Illinois, consisted of eleven case studies and an in-depth analysis of the reports prepared by extended on-site visits to the schools. Each selected school represented a different type of community. The three NSF status studies, then, were designed to survey what the literature revealed about the state of K-12 science education, what professionals reported to be happening, and what professional observers observed in a sampling of schools.

After these NSF studies were underway the third assessment of science as a part of the National Assessment of Educational Progress (NAEP) was conducted. It, too, provided information about the results of instruction in science across the United States. The third assessment included a new battery of items that provided information about the affective outcomes of science education for nine-, thirteen-, and seventeen-year-olds, as well as for an adult sample. Norris Harms, then at National Assessment, was the architect of this information that supplements the achievement data which were the major focus of the two earlier assessments.

In addition, in 1978 Norris Harms of the University of Colorado was awarded a grant to synthesize and to interpret the more than 2,000 pages of information from the three NSF status studies and the NAEP reports. The research effort was called "Project Synthesis" and involved a research team of twenty-three science educators throughout the U.S. The research teams were divided into five focus groups—each charged with examining these components of K-12 science education. These focus groups represented the perspectives of biology, physical science, inquiry, elementary school science, and science/technology and society. Each group worked independently within the same framework: four goal clusters, and critical elements for teaching (i.e., instructional procedures, teacher characteristics, instructional facilities and materials, and others).

The general research procedure characterizing "Project Synthesis" was a discrepancy model which is used more frequently in the social sciences than in the natural sciences. Basic to this design is the promulgation of a desired state followed by descriptions of the actual state. This analysis, then, points the way to the critical third step—identification of the discrepancies between the two conditions. With the identification of such discrepancies, recommendations for future actions are possible.

The three NSF studies, the NAEP data, a review of current textbooks, and some other analyses of the current situation in K-12 science provided a rich source of data for defining the actual state of K-12 science teaching in the U.S. in the late 1970's. The description of the actual state has been called a retrospective synthesis of information.

The prospective synthesis of information used for defining the desired state of science teaching may be more controversial. The information for this analysis was accomplished prior to a study of the surveys used to define the actual state. The information consisted of a wide variety of writings and reports concerned with current projects, viewpoints and research. Some of the reports were derived from careful analyses of current indicators, needs, issues and futuristic planning. Such a prospective synthesis is viewed by many as a qualitative and normative research procedure which is as valid and as productive as more traditional ones.

There is specific literature which deals with ideas, changes, thrusts, directions and other forces which suggest needed directions for science teaching.

Discrepancies between "what ought to be" and "what is" are always expected. However, the identification of specific discrepancies provides both a direction and a framework for immediate action. A careful analysis of such discrepancies also provides a means for making professional recommendations.

This monograph was conceived as a means of transmitting the major results of Project Synthesis to teachers. The discrepancies identified and the recommendations for action are important results that are of interest and of concern to science educators at all levels. To be sure, the information is important for every professional interested in an analysis of where we have been, where we are now and where we go next.

The remaining sections of this monograph include an introduction and overview of the Synthesis study by the staff of the project. This overview provides important background information for reading the remaining sections. The next five sections are edited versions of the five focus group reports prepared by the five chairmen of these groups. The eighth section is a summary of the findings of the entire project by Norris Harms. It is important to note that all sections are in reality summaries of the comprehensive Final Report of Project Synthesis, a report to NSF. That report provides much more detail in many areas, including references to the evidence found in the project data base. It also presents interpretations and recommendations of special interest to audiences other than classroom teachers.

II. PROJECT SYNTHESIS: PURPOSE, ORGANIZATION AND PROCEDURES

Stuart Kahl and Norris Harms
University of Colorado

Simply stated, the purpose of Project Synthesis was to examine the countenance of science education as it exists at the precollege level and to make basic recommendations regarding future activities in science education. To insure that such recommendations be valid, it is necessary that they rest on a sufficiently broad data base and that no important factors affecting the state of science education be overlooked. It is also necessary that the study leading to the recommendations incorporate a broad range of philosophic perspectives regarding the enduring goals of education and that persons of good judgment, representing a variety of substantive points of view, interact in an organized way with the information available to them. The various elements of the operational structure described in this section of the monograph were designed to meet these conceptual requirements.

As mentioned in the Prologue, four comprehensive data bases have emerged which constitute an extremely rich resource for science education. These data bases include three studies funded by NSF and one funded by the Office of Education. The three NSF studies include an extensive review of science education related research, a component of "The Status of Pre-College Science, Mathematics and Social Science Education: 1955-75" (Helgeson, et al, 1977); "Case Studies in Science Education" (Stake and Easley, 1978) which was an intensive study of what goes on in schools and science classrooms; and the "1977 National Survey of Science, Mathematics and Social Studies Education" (Weiss, 1978) which collected data on materials, practices and the leadership in science education. The OE funded project, the National Assessment of Educational Progress (NAEP), has completed its third and by far most comprehensive assessment of science knowledge, skills, attitudes and educational experiences of precollege students, based on a broad set of objectives recently developed by NAEP.

As a set, these four studies provide a more comprehensive picture of science education than has heretofore been available in such an organized and usable form. These four studies became the backbone of the data base from which Project Synthesis worked. That data base was later enlarged to include a survey of journal articles which dealt specifically with goals and objectives in science education. As the study progressed it became apparent that science texts played a dominant role in science education: therefore, the study was expanded to include an analysis of the most widely used science texts as identified by the Weiss survey. Finally, the knowledge and experiences of those working on the project also formed a resource for information which was especially useful in those areas not explicitly covered by the published resources.

Various areas of science education were represented by five working groups which focused on the task from different perspectives. Those were the perspectives of biological science, physical science (including the earth sciences), inquiry, science/technology and society, and elementary school science. Project Synthesis was very much a human endeavor calling upon the intellect, judgment and experience of a number of persons associated with science education. The Synthesis teams associated with each focus group are identified in Parts 3 through 7 of this monograph.

Philosophic perspectives in the field of education are usually embodied in statements regarding the broader aims and purposes of education. One of the first tasks of the project was to identify in very broad terms the most basic goals of science education which could be stated in such a way that one could evaluate the effectiveness of the various elements of the science education enterprise in addressing each of those goals. In order to perform this task, a number of articles and publications discussing goals, rationale or philosophic perspectives in science education were identified. The goals were then sorted into a limited number of goal "clusters" which embodied the primary aims of science education as well as could be determined from existing literature. For the special purposes of this project, it was necessary that the goal clusters meet the following criteria:

1) As a set, they needed to be broad enough to capture the important, generally accepted goals of science education;

2) In both terminology and content, they needed to have meaning for many audiences, including those unsophisticated in science and in education;

3) As a set, they needed to be "unbiased". There had to be at least one "goal cluster" with which any particular person could identify. They could not be "our goals", but rather an organization of "the goals" of science education;

4) They had to be limited in number;

5) Each cluster needed to have some important unifying feature and be distinct from other clusters in some meaningful way. (This does not imply mutual exclusivity, which is probably impossible.)

6) Goal clusters had to lend themselves to operational definitions in terms of student outcomes and elements of practice in science education;

7) Goal clusters had to differ from one another in ways which translate into some differences with respect to the operational definitions mentioned in "6" above;

8) At the end of the study, the goals clusters had to lend themselves to policy-relevant statements.

The term "goal cluster" was used throughout the process. This term reflects the reality that it is impossible to embody all the major goals of science education in a few short statements, but that it is indeed possible to characterize broad goal areas by relatively brief descriptors, useful in discussing major emphases in science education. The goal clusters used in Project Synthesis were determined jointly by the project staff and the leaders of the five focus groups, with useful input from Dr. Bentley Glass and Dr. David Hawkins who participated in the first meeting of group leaders. The goal clusters finally used divided learning outcomes into categories of relevance for 1) the individual, 2) societal issues, 3) academic preparation and 4) career choice. They are defined here briefly, and used later in the Focus Group reports.

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

Goals that fall into Category I focus on the needs of the individual. For example, there are facts and abilities one needs to be a successful consumer or to maintain a healthy body. One should have some idea of the many ways science and technology affect one's life. Knowing that is still not enough. Science education should foster attitudes in individuals which are manifested in a propensity to use science in making everyday decisions and solving everyday problems.

Goal Cluster II: **Societal Issues.** Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

Category II goals relate to the needs of society. They pertain, for example, to the facts and skills a person needs to deal with the environmental and energy issues which affect society at large. In order to vote intelligently on science-related societal issues or participate in responsible community action, not only are specific facts and skills important, but also an understanding of the role of science in society, a knowledge of issues and how science relates to them, and a recognition that in providing the solution to one problem science can create new ones. Of course, to develop informed, concerned citizens and wise voters, science education also must be concerned with attitudes. It must instill in students a sense of responsibility, an appreciation of the potential of science to solve or alleviate societal problems and a sense of custodianship to protect and preserve that natural world with which science concerns itself.

A common element of personal and societal goals is the importance of the applications of science to problems of personal and societal relevance. In order for students to be able to apply science to such problems, it is necessary that they have an understanding of the problems, of the aspects of science which apply to the problems and of the relationship between science and these problems. Students should also have experience in the processes of applying science to the solutions of such problems.

Goal Cluster III: **Academic Preparation.** Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.

Goals in this category pertain to scientific ideas and processes which form a part of the structure of scientific disciplines, which may not be related easily to specific decisions about one's own life or about societal issues, yet which are necessary for any further study of science.

Goal Cluster IV: Career Education/Awareness. Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

Science classes in all disciplines and at all levels which prepare students to make informed career decisions regarding jobs related to science and technology would logically place emphasis on topics and learnings such as: awareness of the many possible roles and jobs available in science and technology including such careers as scientists, engineers, technicians, equipment designers, computer programmers, laboratory assistants, as well as in jobs which apply scientific knowledge in agriculture, nutrition, medicine, sanitation, conservation, etc.; awareness that persons of both sexes, all ethnic backgrounds, wide ranging educational and ability levels and various handicaps can and do obtain such jobs; awareness of the contributions persons in such jobs can make to society as a whole; knowledge of the specific abilities, interests, attitudes and educational preparation usually associated with particular jobs in which individual students are interested; a view of scientists as real people; a clear understanding of how to plan educational programs which open doors to particular jobs; a recognition of the need for science, mathematics and language arts coursework as well as a broad base in the social sciences to better understand the relationship between science and society; a knowledge of human and written sources for further information in all areas listed above.

The original project plan divided activities into three sequential stages which were labeled Phase I: Desired State of Science Education; Phase II: Actual State of Science Education; Phase III: Discrepancies and Recommendations. Although it was not operationally possible to draw sharp dividing lines between these stages, the project activities generally carried out the original intent of those stages. The primary intent of the first stage, "Desired States", was to define the information sought from the very large data base. Largely, that definition consisted of stating in operational terms the conditions of the elements of the educational process which one might expect to find in science education as evidence that it was succeeding, especially in regard to each of the four goal clusters. Phase II activities consisted primarily of examining and digesting the data base to determine the actual state of science education, especially with respect to the "desired states" defined in Phase I. The purpose of Phase III was to identify needs growing out of Phase I/Phase II discrepancies and then to recommend courses of action for meeting those needs. The nature of actions recommended was also influenced by a number of historical and contextual factors which became evident in the data base.

PHASE I: SETTING THE PERSPECTIVE (Desired States in Science Education)

Following the overall design of the study and the development of the goal structure, the focus groups were convened to begin Phase I of the study. They had at their disposal a set of working papers reflecting early project developments described above, a general description of the three NSF studies, and an extensive set of unpublished working papers developed by NAEP in 1974-1975 for the 1976 assessment. The NAEP papers included specific learning objectives which were related to broadly stated goals somewhat similar to the Synthesis "goal clusters".

The task in Phase I was to develop operational definitions of effective science education. This definition took the form of "desired states" of various elements of the educational process. The "desired states" resulted partly from translation of the goal clusters into descriptions of the conditions one would expect to find if those broad goals were in fact being achieved. Primary attention was given to classes of student outcomes and to curriculum characteristics logically associated with those outcomes. For each focus group, a first step was to define the focus area by listing the smaller content domains, or themes, which would become a part of the focus, and then to list student outcomes in each domain which were consistent with the four major goal statements. These domain definitions can be found in the introduction of each of the focus group reports. They will provide the reader a clearer understanding of the perspectives from which the data were addressed, and they serve as a useful point of departure for future re-examination of science education goals.

During Phase I an unanticipated source of information regarding the status quo in science education began to emerge. The investigators' fluency, or lack thereof, in dealing with various questions reflected to some extent the "state of the art" of thinking in science education. It was easy to list traditional student outcomes associated with academic perceptions of the various disciplines (Goal Cluster III). It was also easy to list the kinds of activities (e.g., "hands-on", group discussion, student projects, lectures, etc.) which apparently have an effect on student achievement and attitude. However, some difficulty was encountered in identifying specific learnings which were consistent with the personal and societal goal clusters. It seemed as though new ground was often being broken in documenting the relevance of particular topics and processes for individuals and for society as a whole. It also became painfully apparent that most of the team members were much more fluent with questions pertaining to how to teach science than with questions regarding what to teach and why. However, the task of associating particular classes of learning objectives with each of the four goal clusters was finally completed. This task had considerable effect on the mind-set with which the data were examined during Phase II.

During Phase I it also became apparent that goal clusters were more useful with respect to content areas at the junior and senior high school levels, (i.e., biological science, physical science, and science/technology/society) than with respect to science education at the elementary level or to the general domain of inquiry. For that reason, activities of the elementary and inquiry groups tended to be directed toward general areas which did not always reflect distinctions among specific goal clusters.

The five focus groups used the four goal clusters as one kind of organizer. Conditions were defined which would be expected if the major goals were being met. The focus groups also looked at desired learning outcomes, curriculum features, program utilization, course offerings and enrollments, teacher characteristics and strategies, and evaluation as components of education requiring definition in terms of desired states.

PHASE II: DETERMINING THE STATUS
(Actual States in Science Education)

The task in Phase II was to "digest" the data base as completely as possible. Each focus group spent from seven to ten days of meeting time and at least that much time in homework systematically studying and discussing the information sources identified previously. Each group agreed upon a mode of attack, assigned individual tasks and discussed group interpretations.

Most of the homework time was spent in seeking information which was relevant to the particular perspectives of the various focus groups. Special efforts were made to determine those aspects of the status which had implications for the questions posed in Phase I, but attention was not limited to only those concerns identified in the earlier stage. Group members studied all chapters of each of the three NSF-funded reports and National Assessment data relevant to the particular focus of that group. In addition, the Biology, Physical Science, Elementary and Science/Technology/Society groups analyzed widely used texts (as identified by the NSF surveys) with respect to those questions raised in Phase I.

Much of the group meeting time was spent merging the information and interpretations of the individual members into group approved statements regarding status. Merging raw information about many elements of the educational system into relatively concise interpretative statements (rather than into data summaries) acceptable to all group members, proved to be a difficult task. The group process served several purposes. It resulted in the filtering of individual interpretations which could not be well supported by the data. The group process also resulted in statements which were broad enough to represent the perspectives of the diverse sets of persons serving in each group. These focus group statements reflected the specific information cited in each group report as well as the gestalt developed in studying and discussing the very large data base. Often the specific quotes found in the focus group reports represent only a small sample of the many bits of evidence discussed in the development of particular interpretations.

PHASE III: PROJECT RECOMMENDATIONS
(Discrepancies Between Desired and Actual States)

During Phase III, discrepancies between the "expected" or "desired" states defined in Phase I and the actual states found in Phase II were identified and studied. A number of problems in science education had become evident during Phase II, and there was general agreement within and across focus groups on the nature of most of those problems. Thus, by the end of Phase II, there was an emerging consensus regarding aspects of practice which needed improvement, but mechanisms for effecting those improvements were far from obvious.

A major part of the task at Phase III was to ascertain causal factors which appear to perpetuate problems in science education, and to consider alternative modes of attack on those problems. Various alternatives were considered in light of the contextual factors operating in science education, especially at the district level, and in light of successes and failures in improving science education in the last twenty years.

Parts 3 through 7 of this monograph are the individual reports of the five focus groups. Each group report includes an introduction defining the group's domain of interest, a summary of the desired states identified by the group, a report of the actual states of science education based on a synthesis of the four major data sources, an enumeration of discrepancies between the desired and actual states and recommendations for corrective action. Part 8 represents a synthesis of the results of the five focus group reports. It is a summary of the desired and actual states of science education as well as recommendations derived from them.

It is important to remember that the five groups worked independently, viewing the data from different perspectives, both in terms of group "focus" and of different experiences and philosophies of the individuals involved. The two common elements were the very comprehensive description of science education provided by the data base and the large number of days spent interacting with the data.

III. BIOLOGY EDUCATION

Paul DeHart Hurd (Emeritus)*
Stanford University

INTRODUCTION

The biology focus group developed a "desired" model for the teaching of biology at the pre-college levels of education. The validity of the model rests upon 1) the present character of the scientific enterprise; 2) the current emphasis on scholarship within biological disciplines; 3) biology/social based issues that exist and are likely to persist throughout several decades into the future; 4) personal needs relevant to biology that are evident in contemporary culture; and 5) public reactions to conventional educational goals and practices.

The committee has preserved the basic concepts and principles of modern biology as they have emerged from theory and research. What is different is the educational context in which the biological concepts and principles are displayed. In the desired biology program biological concepts are organized in terms of personal needs, social issues, and career identification. This is in contrast to biology courses organized in ways to display the structure and logic of biology as a discipline.

The conceptual framework for the desired biology program was determined empirically through a normative analysis of relevant biological science and educational literature and a synthesis of the derived information. From the synthesis, generalizations were inferred about various aspects of biological education such as goals, curriculum and teaching practices.

The justification for seeking a new rationale for the teaching of biology stems from recent transitions in the scientific enterprise and new developments in the biological disciplines. The major shifts in science as an enterprise have been its influence on social process and its close alignment with technology. Science and technology have become the two faces of a single "coin." Recently the biological sciences have been influenced by a number of factors including:

1) New theoretical insights (socio-biology);

2) New technologies for research (recombinant DNA);

3) New interdisciplinary perspectives (biophysics, biochemistry, environmental psychology, human ecology);

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4) New concerns about biology and human activities (bioethics, human engineering);

5) A new awareness that although human beings evolved by means of natural laws, survival is now under control of the human species itself; and,

6) New insights into biology as a link between the natural and social sciences giving rise to new cross-disciplinary perspectives (social biology, human ecology, ecological psychology) directed toward comprehending human life as a whole.

The overarching rationale of the desired biology program is the use of biological knowledge to enhance the understanding of oneself and to benefit the quality of life and living for human beings. To achieve these purposes requires the study of the human organism in its natural, cultural and psycho-social environments. The desired biology for pre-college students is essentially a science of human beings focused on human adaptation and future perspectives for human welfare. Biology taught for these purposes involves questions of ethics, values, morals and aesthetics. What a curriculum with these characteristics might be like is presented in the following sections of this report.

THE DESIRED STATE OF BIOLOGY EDUCATION

Objectives and Student Outcomes

The objectives of the desired biology program center on the study of the human species as a part of nature (1) to understand human beings as a distinctive organism; (2) to appreciate the universal human need to be in touch with our own nature, and all of nature; and (3) to learn to live in harmony with nature and to minimize the dissonance between the social and natural environments.

Students are expected to acquire a knowledge of human existence, the realities of society and alternative futures for humankind to improve human adaptability and attain a high quality of life. The biological knowledge for achieving these objectives is not unlike that found in most standard textbooks. However, the use of this knowledge in teaching and living is very different.

The Biology Focus Group identified examples of specific student outcomes consistent with the four Project Synthesis goal clusters identified in Section 2 of this monograph. A few of those outcomes are presented here for the purpose of exemplifying the kinds of learnings which are representative of a desired biology program. For each goal cluster, one sample outcome is presented in each of a number of biology topic areas (e.g., genetics, nutrition, behavior).

Goal Cluster I - Personal Needs

- Genetics: Can interpret basic concepts of human genetics in terms of the implication they have for susceptibility, transmission, probability and meaning of birth defects, genetic diseases, and health maintenance.
- Evolution: Appreciates that changing biological and cultural factors influence our life patterns today and will continue to do so.
- Nutrition: Knows the long-range effects of poor diets (anorexia, prenatal nutrition, aging, hyperactivity and mental ability) and recognizes the necessary changes to improve the diet.
- Behavior: Appreciates that human behavior is influenced by a wide variety of interacting factors, such as the natural, social and cultural environments, genetic makeup, life experiences, personal factors (sex) and learning.
- Continuity: Understands that the continuity of human life on earth is maintained through a process of reproduction.
- Structure-Function: Knows that disease, drugs and life style can disturb the normal balance of the life maintenance systems with the result that optimal health levels are depreciated.
- Diversity: Appreciates that all human beings are unique in the sum of their characteristics - biological, social, psychological, experience, responsiveness, etc.
- Life Cycle: Appreciates the unique and special aspects (both positive and negative) of the various life stages.
- Energetics: Knows that the energy exchange system within human beings is related to a larger energy cycle that makes it possible for all forms of life to survive.

Goal Cluster II - Societal Issues

- Genetics: Knows that genetic principles can be applied to improving plants and animals.
- Evolution: Appreciates the unique contributions of humans to the evolutionary process.
- Nutrition: Knows about and supports research for the improvement of food products and nutrition.

- Behavior: Knows the conditions and effects of chemicals (drugs like alcohol and tranquilizers; nutrients, etc.) used to modify human behavior and the need for social controls.

- Continuity: Recognizes that human population growth can seriously influence the quality of life in various ways (economic, social, food, energy, etc.)

- Diversity: Accepts the notion of diversity as essential to human survival and cultural richness.

- Life Cycle: Understands how achievements in science, especially biology, may influence the life cycle of human beings.

- Energetics: Identifies and evaluates ways in which human beings may influence the energy cycle through changing the biomass (green revolution, hybridization of improved nitrogen fixing plant species, etc.).

Goal Cluster III - Salient Knowledge

- Genetics: Knows some factors which may increase mutations.

- Evolution: Knows that species differ in their adaptive capacity but all are subject to environmental conditions.

- Nutrition: Knows the classes of foods (fats, proteins, carbohydrates) and their biological functions in maintaining growth, energy and health requirements.

- Behavior: Knows that behavioral patterns are distinctive within species and between species (individual and group patterns), but that there are commonalities within species.

- Continuity: Understands the processes of reproduction, sexual and asexual.

- Structure-Function: Knows the structural-functional relations in the organizational levels of organisms (molecule, cell, tissue, organ, organism, population, world biome).

- Diversity: Recognizes the advantages of a classification system in describing and identifying diverse organisms.

- Integration: Understands the importance of unifying and regulatory systems in multicellular organisms.

- Life Cycles: Knows patterns of development among plants and animals.

- Energetics: Understands the significance of various processes of bioenergetics, such as photosynthesis, respiration, digestion, circulation, enzymatic reactions and chemical cycles (nitrogen, oxygen, carbon dioxide, etc.).

Goal Cluster IV - Career Knowledge/Awareness

The desired biology program with its focus on personal and societal needs provides a broad range of opportunities for students to develop an awareness of career choices in the biological sciences, to explore choices that interest them, and, in some instances, to gain basic academic/vocational skills. Almost every topic in biology represents a career endeavor of some person or persons. The teaching task is to help the student understand that biology is a product of human endeavor as are all sciences. The production of new knowledge through research is not the only career opportunity in biology. For every researcher there are many kinds of supportive vocations, such as the work of technicians, laboratory assistants, translators, computer programmers, equipment designers and many more. There are careers that make use of biological knowledge in agriculture, medicine, nutrition, nursing, pest control, sanitation, horticulture, conservation, caring for animals, training of athletes, and hundreds of other fields. There are new careers being developed all the time.

Program Existence

The desired biology program already exists in part in those schools providing courses or special modules on such topics as: (1) environmental or ecological studies; (2) human anatomy and physiology; (3) health - particularly those aspects dealing with maladaptive topics such as alcohol, drugs, tobacco and disease; and, (4) futures in terms of the quality of life.

Program Dissemination

The major factor in the dissemination of a biology program focused on the personal, societal and career needs of human beings is a change in the philosophy, rationale or conceptual framework teachers hold for the teaching of biology. There are a number of introductory, first-year, general education, college biology textbooks that treat biology in the context of the Project Synthesis prospective course. Some 300 colleges and universities now have courses or majors in human biology in which the personal and social implications of biology are considered. It is recommended that these programs be made available to teachers through summer institutes, seminars or in-service programs as means for disseminating and implementing new biology in school programs.

For the qualified biology teacher, the difficulty of disseminating a human biology approach is not so much a problem of learning new subject matter as it is understanding the educational rationale for such a program. The change is not one of biological principles but the context in which they are presented. The shift is from a formal discipline focus to one that centers upon the student as a biological organism living in a cultural and social environment. Essentially this is a wider context for teaching biology and one that is potentially more meaningful and useful to students.

Program Implementation

The desired biology requires no changes in time allotments in schools. It is a course to be required of all students because the subject matter is primarily directed to improving human adaptation on both an individual and social basis. To require the program of all students would mean about a 15 percent increase in biology enrollment over the current number of students taking biology.

Teacher Characteristics

The teacher of the desired biology course not only needs to have internalized the rationale of the program, but also must develop a mode of teaching consistent with the conceptual framework. Effective teaching practices depend as much upon the teacher's personal philosophy as upon instructional skills. Some of the essential teacher attributes for implementing the desired biology program are described under the four goal clusters of Project Synthesis as follows:

Goal Cluster I - Personal Needs

- Seeks and tolerates conflicting points of view when based upon knowledge and encourages discussion.
- Uses discussion effectively to facilitate interpersonal relations.
- Does not force closure - introduces new information, raises new questions, "appropriately" expresses own opinions.
- Knows how to deal with individual and group activities in a variety of situations.
- Respects and cares for adolescents and relates biological knowledge to individual problems.

Goal Cluster II - Societal Issues

- Uses group dynamics in the classroom as an application of larger social issues.
- Uses processes of group problem solving, decision making and conflict resolution.

- Is perceptive of the student's active role in the classroom, community and society.

- Recognizes major biosocial problems and can relate biological knowledge to their interpretation and possible resolution.

Goal Cluster III - Salient Knowledge

- Knows the concepts and principles of biology as they relate to personal needs and social issues.

- Has a knowledge of basic concepts in cognate disciplines (anthropology, psychology, sociology, economics, human geography, political science, future studies) that are relevant to the personal-social-career goals for teaching biology in a human context.

- Recognizes that curriculum and professional development are lifelong processes for teaching problem-centered, action-oriented, personal-social biology.

Goal Cluster IV - Career Knowledge/Awareness

- Knows sources of information on biology related careers.

- Has contacts with working biologists in different research, professional, technological and industrial fields.

- Knows and makes use of community resources for developing a career awareness in students.

Classroom Practices

Methodology. The major adjustments in teaching methodology required for the desired biology program entail:

- A Problem Approach to Curriculum Organization and Teaching—In this approach, elements of scientific knowledge and scientific endeavor are presented in the context of societal issues related to these elements of science.

- Individualization—The goal cluster, personal needs, requires individualized instruction at appropriate places in the curriculum.

- Cooperative Activities—The societal issues goal requires members of the class to work cooperatively in the resolution of problems and issues.

- "Laboratory" Work—Here activities are as much experiential and field-oriented as they are experimental and confined to the laboratory table. Laboratory activities require students to locate information sources (libraries, computer retrieval systems, expert opinion) in some instances and to "discover" information at other times. Whatever methods of investigation are to be used, they are to be justified in terms of the problem. Issue oriented laboratory problems take place in an ethical value or moral context and lead to decisions or consensus rather than to conclusions. Ideally, laboratory activities will be but a beginning to thought, action, experience and learning. An investigation is viewed as a confrontation between a student and a personal problem or societal issue. In this way, it becomes possible to convey to students that scientific knowledge does not exist in a void; it is knowledge of something and for something. We want students to recognize that facts are the means as often as the end of an investigation. The most worthy investigations have tangible results which are useful in: 1) making a decision, 2) taking an action, 3) providing an interpretation, 4) identifying the "real" problem, 5) making an application, or 6) forming a concept. In a personal/social-centered biology program an investigation provides a pedagogical device for students to discover the interconnectedness of events, people, and biological phenomena.

Equipment, Supplies and Facilities. The desired biology program does not place a demand on acquiring new equipment, supplies, or facilities. What is required is the greater use of the natural environment, community resources, and the students themselves as objects of study.

Evaluation

The foci of the evaluation program are: 1) the effectiveness of the student to use a knowledge of biology to interpret personal problems and social issues, and 2) a demonstrated ability to formulate rational decisions in the context of personal problems and social issues.

THE ACTUAL STATE OF BIOLOGY EDUCATION

Goals

Goals of science teaching changed little in the twenty-year period 1955-1975, but currently they are in transition. The science curriculum improvement projects developed during the 1955-1975 period focused on goals related to the conceptual structure of scientific disciplines and their processes of inquiry. Throughout this period the professional literature on science teaching tended to emphasize the need for a broader perspective for science teaching, including societal and cultural aspects, the interrelationship of science and technology, personal and humanistic foci, and decision-making skills. In practice, however, the emphasis has been on vocabulary and narrow course objectives (explicit statements of what is to be learned) as opposed to general goals (e.g., the nature of inquiry or of human beings). There is little evidence that the goals of the federally supported science curriculum projects were ever translated into instructional and testing practices, although these goals are advanced as justification for science teaching. Generally, teachers show little enthusiasm for teaching biology as inquiry. Instruction directs students to the "right" conclusion and little heed is paid to developing an appetite for submitting beliefs to an empirical test. The curriculum is the textbook, and the objectives are those implicit in the text.

A survey of 42 states in 1973 revealed that less than half specify goals for the teaching of science and, for those that did, a majority (70 percent) listed "facts, concepts, principles" and a smaller number (30 percent) cited "process, inquiry, or investigation" as goals of instruction. Compared with acquiring information, all other educational goals are seen as of minor importance. Only 17 percent of teachers feel a need for further assistance in establishing other instructional objectives. Three biology textbooks, Modern Biology and the BSCS "Green" and "Yellow" versions, represent the subject matter taught in two-thirds of the biology classes in the United States, with an enrollment of approximately 3,000,000 students. The extent to which these textbooks also serve as supplementary references with other biology textbooks is not known. In a major way the goals and objectives of these three textbooks are the instructional goals for biology teaching throughout the nation. Each of these books was therefore examined in these terms.

BSCS Textbooks. Objectives are explicitly stated and tend to be reflected in the reading and activities throughout these textbooks in a variety of ways. This is particularly true of the inquiry objectives and objectives pertaining to a historical perspective in the development of biological concepts. This perspective provides opportunities for students to learn about careers by reading about biologists who have made contributions to biological thought. The "Green" version gives more attention to modern biologists and their contributions, while the "Yellow" version emphasizes historical personages.

The objectives of both the "Green" and "Yellow" versions touch on personal and social implications of biology throughout the text but only marginally. While humankind is not neglected, it also is not dealt with in a substantive manner or in a biosocial context. The closing chapters of each text identify major biosocial issues which face human beings today but do not deal with possible solutions. The "Green" version devotes approximately 10 percent of the entire text to biosocial issues, the "Yellow" version, a single chapter. The full import of social topics in terms of moral, ethical, or value considerations is not considered.

Both of the BSCS texts are oriented toward investigative procedures used in scientific research. These objectives represent a range of cognitive levels from simply observing, discussing or demonstrating to making predictions, synthesizing data and hypothesizing.

Modern Biology Textbook. Modern Biology is oriented toward information rather than problems or issues. While the broad goals of Modern Biology are not identified, specific objectives are stated. The objectives of some chapters in Modern

Biology are related to the goal clusters of Project Synthesis, specifically to personal and social problems. Nutrition is a major topic, but topics on food resources and meeting human nutritional needs as biosocial issues are not discussed. Tobacco, alcohol and drugs are dealt with in terms of their effects on the person. Issues such as pollution, the environment and conservation are introduced as major issues, but not in the context of personal and social actions.

For all three textbooks the stated objectives are more discipline-bound than they are a representation of biology in terms of understanding the human species as a biological organism in a social setting.

Instructional Programs

Biology programs are currently being influenced by the "back-to-basics" slogan to stimulate schools to concentrate more on reading, writing and mathematics. The response in biology courses to this slogan is too often a concentration on memorizing discrete facts, justified as basic to understanding biology. A second factor impinging on the teaching of biology is the nation-wide attention to social problems and issues that have a basis in biological knowledge such as environmental management, genetic engineering, energy and the biomass and others. The response in schools has varied from adding new subject matter to regular courses to generating special modules or mini-courses on these topics. In other schools biosocial issues are defaulted to social studies courses. No matter how "basics" and "biosocial issues" are viewed by curriculum developers, they represent pressures on biology teachers to modify their teaching.

Biology teachers who were asked to rank in order of importance conditions influencing their teaching listed: 1) lack of materials for individualized instruction; 2) lack of funds, and 3) inadequate facilities. Other problems identified were: 1) the reading level of and the difficulty of the concepts in textbooks; 2) state requirements for more emphasis upon environmental and ecological studies; and 3) a reduction in science requirements for graduation.

The instructional programs represented by the most commonly used textbooks were determined by a qualitative analysis of the BSCS Yellow, BSCS Green, and Modern Biology programs. Although there are conspicuous differences between the three programs in organization and in thematic structure, there is a common body of biological knowledge represented by the life support systems in plants and animals. Principles of biological evolution and of ecology are used to provide an integrative perspective to the courses. Personal and societal concepts in a human context and career awareness are only minimally treated in the subject matter of these textbooks. The criteria used to choose course content seem to be: 1) to present information sampling biology disciplines such as botany, zoology, human anatomy and physiology, ecological distribution of organisms, genetics, and development; 2) to acquaint students with aspects of scientific inquiry such as making observations, recording information, reporting findings; 3) to develop in students personal scientific attitudes such as curiosity, respect for reliable information, critical thinking, willingness to be wrong, appreciation of science and of living things; and 4) to develop skills associated with inquiry development such as recording observations in tables, charts or graphs, "experimenting" or investigating problems.

The middle/junior high school life science programs emphasize facts about living things such as knowing the structure and functions of various parts of plants and animals, the names of organisms, and the vocabulary used in genetics. Laboratory activities were typically distributed throughout the textbooks and required students to "do things" such as sprout bean seeds, observe the parts of a plant or animal, take one's temperature or compare organisms. There were few experimental activities where students were asked to answer a question or solve a problem by gathering and interpreting information in an organized way. Most students were simply required to measure, count or describe observations in some quantitative way.

In summary, biology education programs are under social pressure for a change in perspective toward the utilization of knowledge. An analysis of existing programs at the secondary level (middle/junior high and senior high school) reveals that discrete knowledge, in and of itself, continues to be the emphasis of all programs. Inquiry is primarily used (if it is used at all) as a means to relay information to the students. Careers in biology-related fields are mentioned but not treated substantially. This is especially true for the middle/junior high school programs for students, many of whom are thinking about their life work. Little attention is given to the personal use of biological knowledge or social issues related to contemporary life.

Learning About New Biology Programs

The lack of a national, centralized educational system in the United States makes the dissemination of information about new instructional programs and materials to thousands of schools a difficult task. National Science Foundation programs have been an effective means for informing school personnel about new biology programs but have attracted less than half the teachers and a smaller percent of administrators.

Half the states have a state science supervisor who disseminates information about new biology programs. The supervisor's major sources of information about these programs were: 1) publishers and sales representatives; 2) professional publications; 3) meetings of professional organizations; 4) federally sponsored workshops; and 5) teachers. Teachers state they receive their information about a new science program from publishers (63 percent), other teachers (62 percent), journals and professional publications (61 percent), college courses (49 percent), and professional meetings (44 percent). Other sources were of lesser significance, with under 32 percent of teachers benefiting from them. Grades 7 through 9 science teachers reportedly learned about new science programs mostly from other teachers (66 percent) and from college courses (53 percent), followed by publishers (37 percent). Less than 20 percent of teachers list inservice programs as a source of information about new curricula.

When the criterion is the usefulness of curricular information, professional publications and professional meetings were judged as the best source. Teachers themselves are a major link in the communication network as a source of curriculum information not only for each other but also for curriculum coordinators, supervisors and principals. Although commercial organizations appear to be an important source of information, they are not judged to be the most useful to school personnel.

Teacher Characteristics

The three NSF science status studies do not separate teachers by science subject taught. Since two-thirds of the grades 10 through 12 science classes surveyed were in biology, we assumed we have a true sample of biology teachers. Using other data, obtained in 1976, it appears there are approximately 36,000 teachers in the high schools who have an undergraduate major in biology and who teach two or more classes of biology. There is an additional population of 15,000 to 20,000 teachers who teach biology who do not meet these criteria. The typical science teacher has nearly twelve years experience and is a male.

While 85 percent of science teachers in grades 10 through 12 teach all of their courses within a single science area, only 76 percent of 7 through 9 science teachers do so. One way of improving junior high science teaching might be to assign teachers full time to their own discipline. Thirteen percent of secondary school science teachers state they are teaching at least one course for which they feel inadequately qualified.

Science teachers, generally, are perceived positively by their students. For example, 76 percent of thirteen-year-old students and 81 percent of seventeen-year-old students reported that their most recent science teacher "really likes science"; and approximately 50 percent at both age levels said that their science teachers are enthusiastic and make science exciting. Teachers perceive themselves as losing status in the schools and under pressure to perform too many non-class duties.

Professional Attributes

Generally, science teachers conform to the value system of the communities in which they work, and this conformity is reinforced by hiring procedures. In most instances, teachers closely fit the neighborhood's majority group image of what a teacher should be like professionally. Within their classroom, teachers tend to avoid discussions of controversial subjects and cling to their posture of authority in order to maintain their social rank, their podia and their seats of judgment.

Professional Affiliations

Most biology teachers belong to organizations or unions; for example, 80 percent of pre-college teachers belong to an AFT or an NEA affiliate; six thousand belong to the National Association of Biology Teachers.

The increase in the collective bargaining strength of teacher organizations has not only effected higher salaries and more fringe benefits, it has resulted also in increased dissension within teaching groups. Teachers are increasing their militancy as a reaction to "riffing", a term applied to 'reduction in teaching forces', and to misassignment. As a result of union action, many school districts have strong seniority clauses in teacher contracts. Consequently, regardless of preparation and/or performance, old teachers stay and new teachers go when enrollments are reduced. Schools, and science departments, have diminishing control over the most important determinant of good learning, the effective teachers.

Teacher Education

Preservice

The training of preservice biology teachers consists of two components: general undergraduate education and professional training. Generally, biology teachers are well prepared in undergraduate biology but not in chemistry, physics or mathematics. The median requirement of biology courses for certification is twenty-four credits, units or hours. However, 21 percent of biology classes are taught by teachers with less than 18 hours in biology. The undergraduate courses taken by teachers are the same courses taken by students preparing for graduate research in biology. The infrequent use of inquiry teaching in biology classrooms seems to be related to the fact that teachers rarely experience it in their college preparation.

More than half of the biology teachers have a master's degree and 75 percent have taken graduate work in a college or university, but for nearly 40 percent this work is not in the subject field they are teaching.

Inservice

The NSF-funded summer and academic year programs have been popular with science teachers as inservice programs. For example, over 50 percent of the teachers have attended one or more NSF summer institutes, while 9 percent have attended academic year programs. The teachers participating in NSF programs tended to be older and male. More teachers from larger schools in the West and North Central regions of the United States took part in such programs than from smaller schools and other states. NSF participants are more likely to use new curricular materials and laboratory activities in their classrooms and to stress student-centered activities. Furthermore, there has been a consistent trend toward better student performance with increased teacher NSF participation. Typically, teachers give a low rating to school-sponsored inservice programs.

Facilities and Equipment

Effective laboratory experiences require adequate science facilities, appropriately equipped for the investigative tasks to be done and with sufficient financial support for maintenance. In most school districts (64 percent) there is a budget for equipment and a budget for supplies. To maintain science laboratories in a satisfactory condition, school districts depend heavily upon the federal government for financial help. About a fourth of science teachers and administrators consider their science facilities and equipment to be inadequate.

The teaching of biology can profit from special facilities, such as greenhouses, nature trails, land or outdoor labs and a ventilated animal house, but only one school in seven has any of these resources. However, only about one in five biology teachers makes use of these resources when they are present. Equipment commonly used in teaching biology appears to be in adequate supply. Most schools have microscopes, models and other materials that are needed, but teachers report they are becoming "run down", and that money is lacking to maintain equipment.

Instructional Practices

In biology teaching, three conditions are most evident: the textbook is the basis of instruction; the teacher determines the tone and type of learning experience; and lecture-discussion is the prevalent mode of presentation. The organizational pattern is five to seven class periods of 45 to 60 minutes each with fewer than 10 percent of the schools having modular schedules. The average class size has been reduced from over 30 in the 1950s to 24 to 25 in the 1970s.

The basic classroom instructional resource is the textbook. It is the "answer place" for teacher questions, almost all of which come from the text and concern terminology and definition. More than 90 percent of 12,000 science teachers surveyed said that texts were the heart of their teaching 90 to 95 percent of the time. The textbook is both the medium and the message, and most teachers do not stray far from its organization and subject matter.

Fewer than half of the teachers use an inquiry approach in teaching; most believe that inquiry only "works" with bright youngsters from intellectually motivated families. According to one of the surveys, teachers think that there has been too much emphasis recently on discovery-learning, hands-on demonstrations, field studies and contemporary topics.

Student Characteristics

The three NSF status studies provide little direct information about student reactions to school biology programs. The information for this section of our report was obtained from studies reported by the National Assessment of Educational Progress.

Science is the favorite subject (first and second choices) for 26 percent of the high school students, falling behind language arts selected by 33 percent, mathematics selected by 31 percent, and social studies selected by 29 percent of the students. Science classes are reported to be boring "always" or "often" by 31 percent of the high school students, "seldom" or "never" by 15 percent. The subject matter is considered "irrelevant" by a third of the students and suited only to the "bright" students.

A different situation is reported for junior high school students. At that level, 21 percent of these students report science is "often" or "always" boring, while 31 percent report that science is "seldom" or "never" boring. Science classes are reported as "frequently" fun by approximately one-third of the students, while an equal number reported that it is "seldom" fun. An analysis of the responses by race indicates that blacks, at age seventeen, found science less boring (27 percent black / 17 percent white), found it more fun (30 percent black / 26 percent white), and indicated more often that they liked to go to science classes (48 percent black / 38 percent white).

About half the students report the subject matter of science as interesting; 22 percent regard science as "too difficult". Fifty-five percent of the students characterize science as "facts to be memorized". It appears that one-half of the secondary students are happy with their science classes, stating the subject matter often makes them curious. Teachers state that developing student motivation is a major problem in teaching science.

Nearly half of the students report they plan to take more than minimal science in high school, while 37 percent report that they do not. About one-third of the students state they would like a career in science or in a science-related field, while an equal number responded negatively. Over 70 percent would like to see scientists at work, and even more (77 percent) feel that they themselves could learn to do science-related work. Nearly one-third feel that working in a scientific field would be boring, while 46 percent of the students disagree. Over one-third feel that studying to be a scientist would take too long and require too much education; a similar percentage disagrees. While 17 percent feel scientific work would be lonely, 54 percent do not. Interestingly, black respondents were more positive (by approximately 25 percent) in their responses concerning science as a possible career.

Students generally feel that science can help solve problems of pollution, energy waste, food shortages, overpopulation and depletion of natural resources. More students feel that science cannot solve problems of disease than feel it can. Students enthusiastically endorse a wide range of actions they would be willing to take to solve world problems. Such actions include using less electricity, walking, riding bicycles, helping with litter pick-up, separating trash for recycling, using economy cars, using less heat in winter and using returnable bottles.

When asked about problem solving in daily life (outside of science classes) students report that they rarely conduct experiments. Half of the students report that they do take measurements, make careful observations, work on one part of a problem at a time, try to find more facts related to a problem and think of various ways of solving problems. Students are confident science can help resolve problems of starvation, energy shortages, prevention of birth defects, saving natural resources, and reducing air and water pollution and say they would support the expenditure of funds for research on these problems.

For the most part, students understand the function of theories in science, how scientists work and how science progresses. Students believe scientists should be allowed to freely investigate most topics. However, they would exercise some controls, especially in such fields as genetic engineering, cloning, biological warfare, human behavior and other controversial societal issues. Students generally support the use of scientific knowledge and have faith in the value of science for resolving world problems.

Student Evaluation and Testing

The NSF Surveys all indicate that administering, checking, returning, and discussing tests occupy much teacher and class time. Testing is considered an essential part of the science curriculum. Laboratory time is often neglected because the results of laboratory work do not "show" on tests. Most tests used in biology are teacher-developed, and teachers are committed to their own testing practices. Thirty percent of teachers test their classes at least once a month while 35 percent report weekly testing. Tests are viewed as a way of knowing "how well" students are doing.

Although tests are considered to be public manifestations of student understanding, they are rarely used to make instructional decisions. Few teachers question the purpose of testing or think of it as any more than a means for providing feedback on student understanding and a means for assigning grades; tests are considered a fixed part of the system and are, therefore, unquestioned.

Standardized achievement tests are of two types: those that compare a student's science achievement with that of his/her peers (SAT, ACT, STEP, ITED) and those administered nationwide. Only one-third of the school districts use standardized tests, such as the STEP and the Iowa (ITED) tests of science. Standardized tests are not a major concern of science teachers; they feel the results of these tests are not valid measures of their local curriculum. On the other hand, they are concerned about the public's attitude toward decreasing scores on college entrance exams (SAT and ACT). Concerns about accountability in education and competency-based science programs have increased since 1970. Most school districts now have an "evaluation officer". However, only 2 percent of the states have established basic science competency levels for graduation from high school, and only 13 percent are planning such procedures.

DISCREPANCIES BETWEEN DESIRED AND ACTUAL STATE OF BIOLOGY EDUCATION

The major discrepancy between the actual and desired biology programs is found in the philosophical or normative assumptions underlying each program. The desired program is a consideration of biology in a framework of the personal and social aspects of human culture and human endeavors. Subject matter is selected for the potential it holds for improving the adaptive capacity of individuals and for advancing the welfare of humankind in general. In the actual biology course subject matter is used to portray the structure of biological disciplines.

Another difference between the actual and desired biology curricula lies in the historical perspective of the two programs. In the actual courses the emphasis is upon the past achievements of the biological sciences; in contrast, the desired course is perceived as a possible history of the future. Expressed in another way, the actual courses present a sample of what is known about biology; the desired program (using the same biological concepts) stresses the use of biological knowledge to further progress toward conditions that are likely to improve the quality of human existence.

In the desired biology program, biology is viewed as part of the social process as well as an intellectual achievement. In conventional biology programs the overall goal is to prepare students for the next level of education; essentially the goal is separated from the student. Conventional biology in high schools tends to reflect a reductionist point of view. The desired biology program is more holistic and interdisciplinary in scope; subject matter is selected from many human sciences, such as human ecology, human genetics, cultural and physical anthropology, environmental psychology and other fields.

In formulating a conceptual framework for the teaching of biology, we have sought to identify a direction for change in teaching practices consistent with current conditions in science as a whole, with changes in biology as a discipline and with contemporary conditions as they exist in society and in the culture. An overview of the discrepancies between the desired and actual states of biology teaching resulting from contrasting philosophical positions is shown in the following summary.

Desired Program	Actual Program
Goals:	
1) Human adaptation and alternative futures emphasized.	1) Minimal consideration given to human adaptive capacities.
2) Biosocial problems and issues as goals.	2) Marginal emphasis on biosocial goals.
3) Inquiry processes unique to biological disciplines.	3) Inquiry skills characteristic of a generalized model of science.
4) Decision-making involving biological knowledge in biosocial contexts.	4) Uncovering a correct answer to discipline-bound problems.
5) Career awareness an integral part of learning.	5) Minimal attention to careers, historical personages highlighted.

6) Value, ethical, and moral considerations of biosocial problems and issues.	6) Value-free interpretations of discipline-bound problems.
Curriculum:	
7) Curriculum is problem-centered, flexible, and culturally as well as biologically valid.	7) Curriculum is textbook-centered, inflexible; only biological validity is considered.
8) Humankind central.	8) Humankind incidental.
9) Multifaceted, including local and community relevance.	9) Textbook controlled, local relevance fortuitous.
10) Use of the natural environment, community resources and the students themselves as foci of study.	10) Contrived materials, kits and classroom-bound resources; use of sub-human species as foci of study.
11) Biological information is in the context of the student as a biological organism in a cultural/social environment.	11) Biological information is in the context of the logic and structure of the discipline.
Instruction:	
12) Individualized and personalized, recognizing student diversity.	12) Group instruction geared for the average student and directed by the organization of the textbook.
13) Cooperative work on problems or issues.	13) Some group work, primarily in laboratory.
14) Methodology based on current information and research in developmental psychology involving cognitive, affective, experiential and maturational studies.	14) Weak psychological basis for instruction in the sciences; behavioristic orientation.
Evaluation:	
15) Testing and evaluation stress the use of biological knowledge to interpret personal and social problems and issues.	15) Replication of assigned information.
16) Student evaluation is based on growth in rational decision-making.	16) Stating "correct" solutions to preplanned problems.

Teachers:

17) Requires a change in perceptions (philosophy, rationale, belief system) of biology teaching to include a commitment to human welfare and progress.	17) Philosophical perceptions not evident in practice, beyond a commitment to biology as a science.
18) Philosophical position influences all aspects of curriculum and teaching practices.	18) Curriculum and teaching practices largely atheoretical and routine.

SUMMARY

Goals

The desired goals of biological education are perceived to be: 1) scientific enlightenment; 2) career awareness; 3) the development of cognitive skills (inquiry and decision making); 4) meeting the adaptive requirements of individual students; and 5) an appreciation of biology in the service of society. Information derived from the NSF status studies indicates these are not the primary goals of the majority of biology teachers.

To the extent that inquiry processes are a part of biology teaching, the emphasis is upon selected skills of investigation such as observing, measuring and classifying rather than the intellectual process of biological research. Rarely is the process of biological inquiry dealt with; rather, discrete inquiry skills are taught. The desired teaching of biology includes the art, habits and skills associated with the utilization of knowledge; these attributes are not reflected in conventional courses. There is almost no emphasis in the regular biology courses on decision-making models, as proposed in the desired course.

Traditionally, biology has been taught in a value-free context based on the assumption that science itself is value-free. To be consistent with the rise of bio-social issues, the teaching of biology in the desired state must of necessity deal with values, morals and ethics. In the past decade bioethics has become a significant biology discipline.

The basic discrepancies between the knowledge goal as it is found in actual biology courses and that goal as set forth in the desired biology course are those of context and scope. Knowledge is identified in both the actual and desired states as the basic conceptual principles identifying living organisms. These pertain to genetics, evolution, nutrition, behavior, continuity, structure-function, diversity and unity, integration, life cycles and energetics. In the actual course these concepts are described and interpreted as attributes of biological disciplines. In the desired state, these biological concepts are described as organizational ideas in personally meaningful, socially relevant and ethically defensible terms. The scope of the desired biology course is extended to include supplemental concepts from such human sciences as anthropology, geography, psychology, sociology, medicine, and from interdisciplinary fields such as biophysics, biochemistry, bioethics, and environmental sciences.

Career education, as the development of students' career awareness, does not exist as a major goal of actual biology teaching. In the desired biology program, the development of career awareness is considered a part of ongoing instruction and of every topic taught.

Curriculum

The discrepancies between goals and curricula of existing biology programs and those suggested by recent advances in science and changes in society are great. The current perspectives on the place of science in society suggest that a valid biology curriculum should match biological achievements with corresponding implications for personal and social living. This approach in no way compromises any concept, principle, generalization or theory in the biological sciences; it does, however, change the context in which biological knowledge is taught from a discipline-orientation to a real-life approach. It also changes the emphasis in teaching from one of simply knowing about biological facts to one that considers how these facts may be used to interpret and possibly resolve personal and social problems of human adaptability and also to an emphasis which anticipates future directions of human progress and cultural patterns.

Instruction

Teachers appear to be moving away from the use of non-school and informal resources (natural environment, museums, invited speakers, television programs) for the teaching of biology, while the desired state of biology teaching is a movement toward wider use of out-of-school and informal resources. The present biology curriculum is, to a large extent, classroom-bound, whereas the desired curriculum is envisioned as functioning in the real world of the students.

In the desired biology program learning is viewed as an interaction between student, materials and the total environment. The teacher serves to facilitate this interaction. Learning, in the conventional biology teaching, is viewed as a process of retention and recall of verbally coded information. In the desired state of biology learning is viewed as information processing. The important learning skills are those which provide access to knowledge and its utilization. In the desired course of biology there is an emphasis upon decision making as well as inquiry skills. Inquiry skills are viewed as useful for understanding how knowledge is discovered, and decision-making skills for understanding how knowledge is used.

Laboratory activities in the actual biology course are typically rituals or dissection activities, and few are long-range. They pose a question which requires a finite, definite answer; laboratory activities are for the most part contrived routines with pre-programmed answers. When biology is taught in a personal and social context (the desired state) and in terms of real-life problems, laboratory investigations involve a combination of human beings, biological concepts and a personal or social issue. The student is nearly always a part of the problem or involved in an indirect way as a member of a population. Thus laboratory activities are viewed as a confrontation between student(s) and real-world situations.

Evaluation

In the actual biology program the major testing activity consists of having students replicate in one way or another the facts that have been taught. In the desired program more attention is given to having students express a line of reasoning in resolving a problem, suggesting a program of action, interpreting a situation and in other ways demonstrating their capability for critical thinking and rational decision making. In actual biology programs many of those attributes are assumed to exist if the student can identify some of the relevant facts.

Teachers

In the desired biology program, teachers are viewed as custodians of a science/technology-based culture with a responsibility to support and enrich its potential. This position is in contrast to teachers of the actual course who view their function as a conveyor of knowledge and measure their success by scores their students make on achievement tests. The major difference between teachers of the desired and actual biology programs is a philosophical one.

Conclusion

The biology focus committee of Project Synthesis believes that the proposed desired state of biology teaching is more in harmony with (1) the current state of science as an enterprise, (2) the disciplines of biology, and (3) contemporary social/culture shifts in the United States, than is the biology program portrayed in the three National Science Foundation status studies.

IV. PHYSICAL SCIENCE EDUCATION*

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As with other areas of science, a study of the status of physical science education soon causes one to face the issue of goals. Who should be taught what science for what purpose? This central issue permeates a review of physical science education and will be dealt with in many ways in the following pages.

Before moving directly to this issue, however, it should be noted that this report on physical science is built on the general organizational structure of the Project Synthesis report. Goal clusters, themes, critical elements, desired states, actual states, and other schemes of organization have the same meaning as reported earlier, and space will not be taken here to define them again.

THE DESIRED STATE OF PHYSICAL SCIENCE EDUCATION

If one assumes that a particular goal cluster is important and that physical science has something to contribute to the attainment of that cluster of goals, there are certain characteristics of education that can be identified as desirable. An important preliminary step of Project Synthesis was to identify many of these desired states. These desired states then were used as a basis for analyzing the research studies under consideration and interpreting their results.

It should be noted that value judgments must be employed extensively in this process. It also should be noted, however, that the interpretation of research results is not restricted by a particular set of such values. The process employed here provides for looking at the results of the research from multiple value perspectives.

In this section attention is directed to identifying the desired state of selected elements of the educational process to attain the four clusters of goals. A description of each desired state generally is presented in the form of a specific example which illustrates the state. The critical elements included in this report of matters specific to physical science include student outcomes and program characteristics. Other critical elements such as teacher factors and classroom practices are omitted in this report because of limitations of space.

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*The domain of physical science as used here includes the earth, atmospheric and space sciences as well as chemistry and physics.

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Student Outcomes

The desired states of the various goal clusters are presented here in the form of examples of student outcome statements. That is, the student, for example, will be able to:

Goal Cluster I - Personal Needs

- Recognize the quantifiable aspects of personal matters and apply them effectively (e.g., estimating amount of paint required, effective scheduling).
- Use knowledge of thermostats, evaporative coolers, heat pumps and common insulating materials.
- Use knowledge of the physics of the internal combustion engine and common hydraulic applications, such as power steering and brake systems.
- Identify the relative energy inputs and outputs of common technological devices.
- Utilize science-based knowledge of home heating systems, knowledge of solar radiation and the use of trees to shield houses from it and knowledge of means for reducing the harmful effects of ultraviolet radiation.
- Avoid some of the hazards of spontaneous combustion, hydrogen generation in automobile batteries, and radioactive materials; and make wise decisions about the use of common poisonous and combustible chemicals, acid/base antidotes, and prevention of food spoilage.
- Recognize the universality of change in one's environment.
- Recognize that one's own opinions are often based on knowledge that may be tentative. Therefore, one should be willing to alter opinions based on new knowledge.

Goal Cluster II - Societal Issues

- Understand the magnitude of societal problems using quantifiable data.
- Make more intelligent decisions about energy issues based on a knowledge of the chemistry of fossil fuels, combustion and new materials for solar energy conversion; and comprehend the physical principles underlying the problems of energy storage.
- Comprehend the origins and limitations of supply of ground water, fossil fuels and mineral resources.

- o Comprehend the dangers, potentials and comparative advantages of fusion and fission technologies.

- o Explain the possible relationships between the polar ice cap size, weather and sea level.

- o Explain how phosphates and nitrates pose pollution problems.

- o Recognize that human activity can seriously disrupt the pattern of change on the earth.

- o Recognize that scientific knowledge is changing and deserves financial support on the part of society in spite of what may appear to some persons to be an inability to obtain final answers.

Goal Cluster III - Fundamental Knowledge

- o Comprehend, apply, evaluate, analyze and synthesize knowledge of fundamental units, derived units and systems of measurement.

- o Comprehend, apply, evaluate, analyze and synthesize knowledge of (a) systems, sub-systems and interactions; (b) homogeneous and heterogeneous substances; (c) chemical elements and compounds; (d) conservation of matter; and heat conductivity, kinetic-molecular theory, gas laws, crystals and physical states.

- o Comprehend, apply, evaluate, analyze and synthesize knowledge of kinetics, dynamics, astrophysics, mechanics of fluids, geophysics, physical geology, weather and climate.

- o Comprehend, apply, evaluate, analyze and synthesize knowledge of energy resources, conservation of energy and other laws of thermodynamics.

- o Comprehend, apply, evaluate, analyze and synthesize knowledge of potential and kinetic energy, wave phenomena, sound, light, electromagnetic spectrum, static and current electricity/electronics, magnetism and electromagnetism, and solar radiation.

- o Comprehend, apply, evaluate, analyze and synthesize knowledge of historical geology and the evolution of planets, stars, galaxies and the universe.

- o Comprehend, apply, evaluate, analyze and synthesize knowledge of the nature of scientific inquiry, uncertainty principle and the history of science.

Goal Cluster IV - Career Preparation

Make appropriate career-related decisions based on competencies in the areas of personal need, societal issues and fundamental knowledge as stated in Goal Clusters I, II, and III above.

Program Characteristics

The desired characteristics of a school science program obviously are a function of its goals and will vary accordingly. Good science programs intended to achieve the full range of goal clusters described above will have many of the following characteristics:

- o Opportunities should be provided to pursue individual needs, goals and interests; e.g., provisions could be made for modularity, a project approach or time periods for investigating individual topics.
- o Opportunities should be provided to apply science content and processes to real-world problems that have no "pat" solutions but require trade-offs (optimization).
- o Personal needs, societal issues and career preparation should be considered intrinsic to all facets of the science program.
- o Basic concepts of physical science should be dealt with in a discipline-organized pattern at some point in the total program.
- o Basic concepts of physical science should be dealt with in the context of socially relevant problems at some point in the total program.
- o Opportunities should be provided to interact with people working in science including scientists, technicians and others in science-related fields.
- o Illustrations should be provided of persons with different lifestyles, socioeconomic status, ethnicity and sex who are participating fully in the scientific enterprise.
- o Emphasis should be placed on the means by which scientific knowledge is generated.
- o Within the total program, learning experiences should be included which provide:
  - laboratory experiences including opportunities to acquire information inductively;
  - out-of-school experiences;

- opportunities to look outward from a discipline to find understanding of its problems;

- illustrations of different problem-solving styles;

- exploratory activities that involve risk-taking, guessing, hypothesizing, etc.;

- opportunities to participate in actual or simulated research activities;

- opportunities to develop more advanced mathematical techniques as applied to science matters;

- opportunities to develop reporting and writing techniques; and

- opportunities to develop ability to read science materials.

THE ACTUAL STATE OF PHYSICAL SCIENCE EDUCATION

The science curriculum of U.S. schools has remained relatively stable during the last two decades (Helgeson, et al, 1977, p. 170) and varies little from one place to another as evidenced by data given in both the Weiss (1978) and Stake and Easley (1978) reports. What then is the nature of this rather stable and uniform curriculum?

A beginning place for examining the objectives of science education in the schools is by examining its relative importance in the curriculum overall. Science is not one of the top priorities and is not perceived as basic. There are exceptions; for example, physics, chemistry and advanced mathematics for the more able students "were being protected tenaciously by teachers in those departments in most high schools." On the other hand, the student body at large viewed science as having "rather limited value". Or to put it another way, science as general education "showed no signs of either congealing as an educational cause nor of gaining general support from the public," (Stake and Easley, 1978, p. 12:1). This picture is further substantiated by the fact that high school graduation requirements in science typically are only one year (Weiss, 1978, pp. 24-26) and that the average time spent on science K through 6 is much less than on mathematics and somewhat less than on social studies (Weiss, 1978, pp. 50-51). Forty-seven percent of science teachers are convinced that a significant problem is the general belief that science is less important than other subjects (Weiss, 1978, p. 158). This relative position of science education with respect to the rest of the curriculum is rather consistently held by teachers, administrators, and parents (Stake and Easley, 1978, p. 17:9).

It also should be noted that the purposes of the teachers in the schools are not always the same as specialists in either science education or general curriculum. Many of the aims that have been promoted by the leaders in the field over the last two decades are not really accepted by teachers. The emphasis upon inquiry and problem solving by science education leaders has been strong for the past twenty years (Helgeson, et al, 1977, p. 175); yet, these concerns and the desire for increasing emphasis upon technological and societal issues (Helgeson, et al, 1977, pp. 182-183) are not reflected in school practice or in the views of teachers and administrators.

The difference in objectives found between the practitioners in the schools and the specialists in curriculum or in science education is apparent in examining the role of science in general education. In contrast to the specialists, the schools appear to have downgraded science as part of general education, even though one of the aims of science education as seen by practitioners is to provide all students with some exposure to science.

By and large science is not seen as particularly important except for the more highly motivated or gifted students (Stake and Easley, 1978, p. 12:20). Science literacy ceases to be a goal after grade 10 and science classes in grades 11 and 12 are designed for the high ability student (Weiss, 1978). In many ways it seems that senior high school science departments have given up on science as general education for all as their primary goal and instead have focused upon doing a quality job with more able students. The primary concerns of the schools seem to be "achievement on the simplest of tasks taught, while science departments were concerned about some of the most difficult," (Stake and Easley, 1978, p. 19:8).

In trying to understand the situation and determine why science is given the relative importance that it is, one must examine the school scene closely enough to see what the real primary objectives are. According to the Case Studies, socialization is this primary goal:

> "Such socialization in the classroom was pre-emptive in that it seemed to get immediate attention almost whenever an opportunity arose. Other learnings were interrupted or set aside, not always by choice, to take care of: an effort to cheat, an impending daydream, or willingness to accept a grossly mistaken answer. . . to that end, and also to help the teacher survive daily crises, the new teacher learned how to use subject matter to keep control of the class, what questions to ask which student to head off a prank, what homework to assign to keep the study period quiet, and in many more subtle ways (familiarization, etc.). Although some people are dismayed that so much of the school day goes to administrative routine, few people are protesting the portion that goes to socialization," (Stake and Easley, 1978, p. 16:25).

Another critical factor is the pervasive emphasis upon preparation for later work. The implicit objectives of science instruction which emerge from the Case Studies suggest that the science curriculum in most secondary schools is primarily viewed as providing background material for later work. Secondary school biology, chemistry and physics courses appear to place little emphasis on personal needs, stressing instead those elements of the discipline that will best prepare students for advanced work.

Goal Clusters

A complete examination of science education objectives must include viewing them from the perspective of the four goal clusters. In this regard, it is apparent that Goal Cluster III, fundamental knowledge, receives much greater attention than the other three. With respect to personal needs, for example, the emphasis is not great.

The interface between science, technology, and society also is not given very high priority. In the senior high school, attention to these matters is restricted by the college preparatory goal. Teachers want to teach what the students will need for college; parents want the same (Stake and Easley, 1978, p. 12:19). This preparation function is given high priority and seems to restrict attention to societal needs in spite of the fact that the number of environmentally oriented courses in the schools has increased in recent years on an elective basis.

Although fundamental scientific knowledge takes second place to the basics such as reading, arithmetic and spelling, it is clear that within the physical science area fundamental knowledge takes precedence over the other three goal clusters. The focus of physical science programs is upon basic scientific knowledge rather than its personal applications, its relationship to societal issues, or career preparation. School science in the U.S. is probably strongest in regard to transmitting fundamental knowledge, particularly to those who are in the upper third of the ability-achievement level distribution.

Student Outcomes

The major source of information on student outcomes is that contained in the reports of the National Assessment for Educational Progress (NAEP). This information is of particular interest as it relates to relative outcomes with respect to the various goal clusters and comparative information in the affective domain.

It appears that the apparent lack of attention to Goal Clusters I, II, and III is reflected in the student outcomes as measured by the NAEP Science Assessment. For instance: (a) only about 20 percent of students know that world population is increasing exponentially, (b) only about one-third know that plastic in synthetic fibers is made from oil, and (c) almost two-thirds erroneously believe that the major cause of air pollution in most large cities is factories rather than motor vehicles.

In the affective realm, the NAEP data indicate that students definitely perceive science as being useful (now and in the future); they think it should be required; and they generally have good feelings about science class. Even though the popularity of the natural sciences increases from elementary school through senior high school, it still ranks last in popularity behind the other three basic areas: mathematics, English and social studies.

With respect to measurement of student outcomes, another fact is of interest. In states with minimal competency testing programs, science often is not included

(Helgeson, et al, 1977, p. 156). This fact is another reflection of the relative importance given to science in the schools.

Program Characteristics

The studies under consideration give a picture of science education in the United States which is charaterized by remarkable similarities across the various school systems studied. While there is commonly a great diversity of science offerings within a given school setting - in terms of both the courses offered and the teaching styles employed - patterns are similar across the country.

Within this rather uniform pattern, a striking characteristic is the general lack of instruction in the physical sciences at the senior high level. The data clearly show that middle school students take courses in physical science, but at the senior high school level most students do not take physical science (Weiss, 1978, p. 58, 73-74). A minority of students take physics and/or chemistry, most often in preparation for going to college, but general education in the physical sciences is notable by its absence.

Another striking finding of these studies is the heavy reliance upon textbooks as the determiners of the curriculum. This finding is even more striking when one realizes the great similarity found in the various textbooks utilized for given courses. "Behind nearly every teacher-learner transaction reported in the Case Studies lay an instructional product waiting to play a dual role as medium and message. They commanded teachers' and learners' attention. In a way, they largely dictated the curriculum. Curriculum did not venture beyond the boundaries set by the instructional materials," (Stake and Easley, 1978, p. 13:66). This picture of the curriculum is made more complete by examining the way in which the textbook is employed. It was found, for example, that the typical method of presentation in elementary school science was "assign-recite-test-discuss". Basically, elementary science is learned by reading (Stake and Easley, 1978, p. 13:5).

The inquiry approach which has been so widely touted in recent years is not evident. The use of innovative materials was "relatively rare". Among numerous classrooms visited by Case Study personnel only three were identified in which teachers were using an approach of the type that has been promoted by so many in the leadership of science education in the last couple of decades. "Only a few teachers remained enthused about those innovations, most disparaged them and appealed for a 'return to the basics' " (Stake and Easley, 1978, p. 13:2). Although a "significant" percentage of districts, schools and teachers reported they were using the materials developed under NSF sponsorship, that is, materials designed to involve "inquiry teaching", a low percentage of science classes actually were found to be using "hands-on materials which accompanied textbooks," (Weiss, 1978, p. 79-85, 99). Many teachers feel a need for assistance in implementing inquiry/discovery approaches (Weiss, 1978, pp. 79-85, 97).

Given the general bounds of the curriculum as determined by the textbooks and the lack of inquiry teaching as noted above, there was, however, considerable variation within these boundaries. "It was our observation that the teachers in all our sites had a great freedom to teach largely what they pleased. This is a freedom within limits - and, if they approach those limits the parents or Board objected. They were obligated to organize their work in most of these schools around a certain syllabus or set of topics. But, in a high majority of schools, teachers were not obligated to use the same tests or quizzes other teachers used. . . we found that the teachers taught in largely different styles and, at least in the short run, covered quite different ground; that they felt strongly about this opportunity and privilege to direct their own work; that most administrators and parents agreed that they should have this responsibility - yet, we heard many from all groups urging a 'return to the basics' and a need for more uniformity of curriculum," (Stake and Easley, 1978, p. 13:37). In summary, teachers accepted the boundaries imposed by the textbook and exercised their freedom of choice within those boundaries. . . . in most places a teacher assumed the role of arbiter and authority. . . but, arbiter much more than authority when it came to the curriculum," (Stake and Easley, 1978, p. 13:59).

Among other matters worthy of note is the finding that electives focused upon popularizing science were common. There were numerous new programs and course offerings designed to make science relevant to contemporary society (Stake and Easley, 1978, p. 12:42). Environmental concepts, societal concerns, interdisciplinary relationships and world problems are emphasized in a variety of courses that have been developed (Helgeson et al, 1977, pp. 24, 35). Both the number of alternative materials available and enrollments in such courses have been on the increase (Helgeson et al, 1977, pp. 24, 35). At the same time, it must be noted that there was some tendency for such elective programs to be curtailed due to the current pattern of budget restriction (Stake and Easley, 1978, p. 12:44). It should also be mentioned that while there may be a great variety of such "relevant" course offerings, they are reaching a limited audience and are often designed for the lower ability students.

While the laboratory approach to teaching science is widely espoused, the results of these studies do not indicate that laboratory science is practiced to the extent sometimes believed. "In half the high schools, laboratory science was reported to be nearly impossible to conduct because labs were run down or ill-equipped. . ." (Stake and Easley, 1978, p. 13:63). Laboratory exercises, where used, tend to be just that - exercises - rather than explanations of genuine phenomena in settings in which outcomes are not known in advance. The current tendency, as evidenced by time devoted to such activities and the materials being utilized, is to place less emphasis on laboratory activities and field trips (Helgeson et al, 1977, p. 30). It was noted in the Case Studies that while there were "some outstanding examples of school science outings", in general, out-of-school activities in the area of science were relatively few. The use of guest speakers and field trips is relatively rare (Weiss, 1978, p. 103).

With respect to individualized and self-paced instruction it appears that a very small number of students receive these modes of instruction in spite of the efforts that have been made to promote their use in recent years (Helgeson et al, 1977, p. 35). Audio-tutorial or videotape courses were not mentioned by any observers in the Case Studies. In technological terms, American school science is still in the 19th century despite the use of occasional films in many classrooms. Few post-1950 technologies are used in any significant way.

Finally, it should be noted that there is little articulation between the various levels of schooling, i.e., elementary school, junior high school and senior high school (Stake and Easley, 1978, p. 13:7). Approximately half of the science teachers view this as at least "somewhat of a problem" (Weiss, 1978, p. 158).

Textbook Analyses

In view of the overwhelming influence of the textbook in determining the curriculum of schools as reported above, it was evident that any attempt to understand what the content of the curriculum of the schools is must involve an examination of the textbooks currently employed. Such analysis was not a part of any of the four studies under consideration. Consequently, sample analyses were conducted of popular textbook materials in view of their overriding importance. While it was reported in the OSU study (Helgeson et al, 1977) that the materials produced in the last two decades place less emphasis on "practical" science and, until recently at least, on the interaction of science and society, a more thorough examination clearly was in order.

The net results of the sample analysis is that little attention is given to Goal Clusters I, II and IV in the materials currently employed. The number of books which give significant attention to such matters are few, and in those few cases the attention given is not nearly as great as that given to fundamental knowledge. In physics, for example, the materials range from textbooks which make only a passing reference to societal issues to a book which is one of the few exceptions, namely, the Project Physics course. To the extent that history is woven into the fabric of this text, it may be described as having a societal dimension, even though it does not address contemporary problems in great detail. An "add-on" essay at the end of the book discusses the broad societal dimensions of physics and makes the case for basic research in terms of eventual applications. Career aspirations are addressed in a 16 mm film. In summary, this text attempts to present traditional physics in an historical and humanistic context. It does devote attention to societal issues, personal needs and career information, contrasting with other materials on the market. Other examples of even a modest attention to personal needs, societal issues and career preparation are hard to find. The vast majority of physical science textbooks used in schools give no significant attention to these matters.

Program Adoption

Given the teacher freedom and textbook-dominated curriculum noted above, it is of interest to note that textbook selection becomes the critical point in program adoption; the mechanisms for selecting textbooks are of considerable interest. There is general agreement that teachers either individually or in committees, principals, and district supervisors (where they exist) are involved in the process. Parents, students, and board members typically are not involved (Weiss, 1978, p. B:48-53). Since, as mentioned earlier, teachers perceive "obtaining information about instructional materials" as one of their most frequently unmet needs for assistance, they may face some difficulty in their role of selecting textbooks.

They may be selecting textbooks without up-to-date information about the full range of materials available.

A related matter is the movement of schools toward centralization of development, planning or revision of curricula along with a simultaneous decentralization of administrative authority (Stake and Easley, 1978, p. 17:9). This decision-making process in terms of curriculum obviously is worthy of further study.

Beyond the question of how a particular program is chosen it is important to look at the means by which the program is supported. ". . . Teacher support systems are weak and need vitalization. The teacher having difficulty carrying out an ordinary science teaching assignment has been seen to be without sufficient aid, though many agencies exist for the purpose of providing aid. Teachers told us that their resource people largely do not know the realities of their classroom situation. Potential alleviations are seen via better curricular materials, institutes for teachers, teacher centers, and teacher networks," (Stake and Easley, 1978).

The most direct support available in many school districts is a science supervisor or other curriculum specialists. It is noted that such ". . . persons in the district office would put out bulletins from time to time on curricular matters, that important planning would be done by committees of teachers and administrators and other resource personnel, and that the teacher seldom was personally in touch with a curriculum coordinator per se. . . . There were few people available outside the classroom to provide quality control for the curriculum and assist teachers with pedagogical problems," (Stake and Easley, 1978, p. 16:43).

The clear impression conveyed by these studies is that most secondary schools are conservative organizations which tend to resist change. Since teachers are isolated from market pressures and the corresponding demands for innovation, efficiency and performance, few are motivated to explore alternative course options in trial settings.

Program Implementation

Exposure

The actual implementation of science programs in the schools is best described in terms of course offerings, enrollments and materials utilized. While the data indicate that the <u>percentage</u> of students taking science courses both in grades seven through nine, and in grades ten through twelve, has increased since 1955, in the last few years it has remained relatively constant, or in a few instances has shown a slight reduction. Earth science courses, for example, have experienced a rapid expansion from 1955 through the 1970's (Helgeson et al, 1977, pp. 21-25). While the percentage of students enrolled in physical science has declined somewhat since the early 1970's, percentage enrollments in advanced courses (second-year biology, chemistry, physics) have shown a steady though slow increase. Another change since the late 1950's is a substantial increase in the number of alternative science courses being offered to students (Helgeson et al, 1977, p. 29).

With respect to physical science, several enrollment trends are of interest. Enrollments in general science courses at the junior high school level are decreasing, while increasingly courses at this level are offered as life, earth and physical science courses (Helgeson, et al, 1977, p. 71). For a large percentage of students the last physical science course completed is in the 9th grade. About 50 percent of secondary school students complete their last science course in the 10th grade, but in the vast majority of cases this is biology (Helgeson et al, 1977, p. 71).

Teachers

The Case Studies tell us that the teacher is the key to effective science instruction. Whether teachers are selected to fit the image which the community has of itself or whether they are chosen for their academic qualities, good science instruction takes place in classes where teachers are motivated, well-trained in their subjects and enthusiastic about working with young people. Nevertheless, the majority of the nation's teachers serve as managers of instruction rather than as intellectual questioners. There are few incentives for the latter role while working conditions in many schools demand the former.

In the view of the key role played by the teacher as described above, any insights gained as to teachers' philosophy and mode of operation would be most valuable in understanding how schools operate and in finding possible ways to change them in the future. It appears that teachers have two primary concerns: (1) wanting students to perform well in the classroom, and (2) meeting the expectations placed upon them as teachers (Stake and Easley, 1978, p. 15:14). These concerns cause philosophical issues to take second place to the personal problems faced by teachers, these problems being in particular to (1) obtain the respect of students, and (2) motivate them to do as well as possible in school functions. As a result, subject matter becomes simply the vehicle by which the teacher would establish this personal competence. The subject matter as a direct focus of attention because of its intrinsic value becomes a matter of secondary importance (Stake and Easley, 1978, p. 16:7).

Thorough examination of the Case Study findings gives a strong indication that the basic problem with the proposed reform of science education as reflected in the new NSF-sponsored curriculum materials of the last two decades lies in the differing outlooks that teachers and the best school personnel have about educational objectives and practices (Stake and Easley, 1978, p. 16:11). Teachers play a key role and the values they hold about educational objectives and classroom practices are not the same as those of the people who have been promoting change in the schools. Among the viewpoints held by teachers concerning educational practices which contribute to this conflict are the following:

1) Intrinsic motivation of students is essential;

2) Attention to directions is essential;

3) The most reliable learning will occur when assignments are properly carried out;

4) Frequent testing is important (Stake and Easley, 1978, p. 16:22).

The picture which emerges is one in which teachers are committed to school as an institution and to helping students succeed in that social system as an end in itself (Stake and Easley, 1978, p. 16:26.3). A major part of the socialization process is helping students prepare for the next school year so they can continue to succeed within this setting (Stake and Easley, 1978, p. 16:22). "Putting it in a nutshell, most teachers seem to treat subject matter knowledge as evidence, and subject matter as the means to, the socialization of the individual in school. On the other hand, most subject matter specialists treated socialization as a necessary evil, to be gotten out of the way early - for it is only a means to a greater end of subject matter knowledge," (Stake and Easley, 1978, p. 16:24).

Classroom Practice

An examination of classroom practice probably should begin with a matter noted earlier, namely, that inquiry teaching as defined by the NSF-sponsored curricular programs of the last two decades is by and large missing from American schools. These programs and other experience-based learning approaches are shunned. The major reasons cited in the Case Studies for this situation include, first of all, a philosophic persuasion that is strongly biased toward the textbook approach. The textbook is viewed as the authority and, furthermore, teachers are convinced that learning from printed materials is a discipline that students should learn. The second major factor is the set of frustrating and difficult problems with which a teacher is confronted in attempting to implement an experience-based approach. It is claimed that even appropriate education of the teachers does not result in elimination of this frustration (Stake and Easley, 1978, p. 15:6-7).

While adequacy of science facilities is perceived as one of the most important conditions necessary to a good science program (Helgeson et al, 1977, p. 88), and approximately 25 percent of teachers sampled in the Weiss survey indicated that facilities presented serious problems, one received the impression from the Case Studies that most school science facilities are at least marginally adequate. There surely would be more problems if inquiry techniques were more widely used, but classes which require children to sit at desks while reading texts and responding to teacher questioning do not require creative design.

The Case Studies report large variations in the use of laboratory facilities and equipment. On the other hand, it is apparent that virtually no use is made of out-of-school resources which could be employed to reinforce formal classroom work. This trend is likely to be accelerated by the movement toward "basic" education which will surely increase the pressure placed upon schools to have children spend more time on programs which emphasize facts and rote learning. One can speculate here that the contrast between the variegated external world and the austere life of the classroom (as contrasted with school activities which take place in hallways and cafeterias) may be a major contributing factor to the boredom and lack of motivation of youngsters which many teachers report as presenting a serious problem.

Little evidence emerges from the Case Studies that equipment shortages constitute serious problems, primarily because school science is so dominated by textbook approaches. One can admittedly argue that the existence of greater equipment resources would stimulate alternate approaches to teaching and learning, but one receives the impression that other barriers to innovation and the implicit goal of socialization would tend to retard the effective use of additional equipment even if it were available.

In summary, the picture one acquires from these studies of classroom instructional practices is that they are not consistent with the objectives commonly believed to be those of science education. The goals and objectives one would infer from classroom practice are not those commonly stated and promoted.

Student Characteristics

The obvious major characteristic of students which emerges from the studies is an apparent low motivation, at least as perceived by teachers. Lack of motivation is viewed as a major problem, and it is a common professional topic in teachers' lounges (Stake and Easley, 1978, p. 15:23). Sixty to seventy percent of grades seven through twelve teachers felt that "lack of student interest in subject" was at least somewhat of a problem (Weiss, 1978, p. 158).

Another student characteristic that poses a learning difficulty as perceived by teachers is poor reading ability. Seventy to eighty percent of teachers, grades four through twelve, feel that "inadequate student reading abilities" is a moderate to serious problem (Weiss, 1978, p. 158). It is reported that 40 to 44 percent of secondary principals agree with teachers about reading problems, but few perceive lack of student interest as a problem in science (Weiss, 1978, p. B:131).

The matter of student motivation can be viewed with respect to the grading system. Competition in the classroom and the grading system are important positive contributions to motivating the academically able student (Stake and Easley, 1978, p. 15:23). On the other hand, "the middle range of students is seen as being indifferent to grades in districts large enough to have a highly stratified student body." This situation, along with the fact that the lower range of students often <u>is</u> somewhat interested in grades, is substantiated by data other than that reported in these studies (Stake and Easley, 1978, p. 15:30).

Student attitudes toward science and society also are of interest. The NAEP investigations indicate that students feel that they can contribute toward the solution of certain problems such as energy waste, accidents and pollution (NAEP C03A01), and they definitely are willing to get actively involved in helping to solve world problems (NAEP C03A02). Approximately one-half of thirteen- and seventeen-year-olds indicated that they "often" to "sometimes" use scientific approaches when solving problems outside of class (NAEP C04A07), and most feel that science and technology can help solve such problems as pollution, disease and drug abuse (NAEP C05A02).

On the other hand, only about half of the students seem to know that the application of science knowledge and technology can cause problems as well as solve them. Such naivete is another confirmation of the fact that Goal Cluster II, societal needs, is given little attention in the curriculum.

Another student characteristic provides insights as to the role of secondary schools in providing general education in science. Physics and chemistry students are not average students. The type of students who select physics, for example, consistently tend to be above average in IQ, interested in mathematics and science, and interested in careers that will use science (Helgeson et al, 1977, p. 35). The average student gets no physical science in senior high school.

ANALYSIS OF DISCREPANCIES BETWEEN DESIRED AND ACTUAL STATE OF PHYSICAL SCIENCE EDUCATION

In this section the value judgments of the physical science focus group become more explicit as their key messages are explicated as background for the recommendations to be made in a subsequent section. These value judgments become apparent as discrepancies are identified between the desired state and actual state of physical science education. The identification of such discrepancies by its very nature is somewhat negative, and it should be understood that this identification of discrepancies is not intended to paint a picture of physical science education as being "all bad". Each of the two major discrepancies identified is followed by a key message, more positive in tone, which points toward significant potential change in physical science education which would be of benefit to American youth.

Narrow Goals

While the acquisition of fundamental knowledge about the physical sciences is an acknowledged goal of instruction, this goal tends to be used in a rather narrow manner and to the exclusion of the other goal clusters of personal needs, societal issues and career preparation. The results of the four studies make it abundantly clear that only the one goal cluster gets significant attention. In addition, the focus upon the textbook as authority, the lack of laboratory work and the overwhelming avoidance of "inquiry teaching" raise serious questions as to whether or not this fundamental knowledge is pursued in a context where problem-solving and applications of knowledge are given significant attention.

Key Message #1: The sciences, especially the physical sciences, provide a context in which students can acquire information and processes of problem solving and learn how to apply them to identification and resolution or management of personal and societal problems. The knowledge and processes of the physical sciences are applicable to all four goal clusters and instruction should be broadened to give attention to all four.

Physical Science Not Valued

Science, especially the physical sciences, is not a valued part of the public school curriculum of general education for all students. The physical sciences are given little attention in the general education requirements of students, especially in the high school years.

The only widespread, systematic exposure to physical science is in the science programs of middle schools. The physical science instruction at this level often is limited by: (a) a lack of equipment, (b) teachers who are not adequately prepared in all areas of the physical sciences, (c) a textbook emphasis with resultant limited instructional approaches, and (d) a narrow set of goals as described previously.

Physical science in the senior high school is best characterized as elitist. Enrollments in physics and chemistry are low, limited to some of the students who are preparing for college and/or are especially interested in science-related careers. Enrollments of young women and minorities are low, with resulting far-reaching social implications.

Key Message #2: Physical science should become an important part of general education for all students at all levels, including the senior high school level. The physical sciences should be an important part of general education because appropriate experiences with the physical sciences can contribute to the development of important cognitive skills; and knowledge about the physical sciences and the ability to apply the methods of scientific analysis to personal needs and societal issues are of major importance in today's world. Students can be expected to apply their knowledge about science to situations they encounter in their daily lives only if they are specifically taught to do so and are given opportunity to practice these skills.

RECOMMENDATIONS

The selected recommendations presented in this section are an outgrowth of the analysis of the extant educational situation as described previously. Major recommendations are provided with a brief rationale for each one and an elaboration in the form of a series of more specific and detailed recommendations.

Recommendation #1: The goals of the physical science education should be broadened to include the frequently espoused goals of American education which deal with personal needs, societal issues and career awareness in addition to the typical and important fundamental knowledge goal, and should be extended to include all levels of the school program from kindergarten through the senior high school.

The current situation in physical science education, as indicated earlier, is one of considerable discrepancy between actual states and the ideal in terms of the breadth of goals and the extent to which they are pursued in the school systems. Physical science education has important contributions to make to the development of cognitive skills, the resolution of many personal needs, the resolution of numerous societal issues, and entry into many occupations and professions. Positive change with respect to educational goals in the area of physical science education will require that many matters, including the following, be attended to:

1) The goals of physical science education programs should include acquisition of physical science knowledge and scientific problem-solving skills, and ability to utilize this knowledge and the processes of scientific problem solving in dealing with personal and societal problems and issues as well as career decisions.

2) These goals should extend to all levels of the educational program for <u>all</u> students even though the relative emphasis will vary from school to school, and even within schools, according to such factors as student age, interests and long-term goals, particularly with respect to career preparation.

3) For each of the four major goal clusters, explicit selection criteria for objectives should be defined and all objectives carefully evaluated on the basis of the agreed upon criteria. These specific objectives must take into account the importance of all goal clusters, and relevant selection criteria should be drawn from the physical science disciplines themselves, the psychology of learning, and various student characteristics such as age, mental ability, interests and goals.

Recommendation #2: Existing physical science programs should be modified and new programs developed to provide all students at all grade levels with a broader and more extensive experience especially with physical science content and processes as they apply to the goal clusters of personal needs, societal issues and career awareness.

The rationale for this recommendation is an obvious outgrowth of the synthesized findings from the four data bases used in Project Synthesis. They clearly indicate a general lack of attention to personal needs, societal issues and career awareness in existing physical science courses. In addition, there is an obvious absence of physical science experiences for most high school students (i.e., those not taking physics or chemistry) and a tendency for women and minority students to avoid existing high school physical science courses. A further indication of the importance of this recommendation is the relatively low level of understanding among seventeen-year-olds and adults of ways in which basic physical science principles are applied and relate to personal needs and societal problems. The specific facets of this broad recommendation include the following:

1) New programs for grades seven through nine should be developed and disseminated, and existing programs modified to give greater

emphasis to the goal clusters of personal needs, societal issues and career preparation.

2) Existing chemistry and physics courses should be modified to give a more appropriate emphasis to the goal clusters of personal needs, societal issues and career preparation.

3) New physical science programs for grades nine through twelve should be developed and disseminated which emphasize the goal clusters of personal needs, societal issues, and career awareness and are appropriate for and attractive to the majority of students (including women and racial minorities) not now served by the high school physics and chemistry courses.

4) Interdisciplinary programs (courses, modules, activities, etc.) should be developed which focus on personal and societal needs and incorporate the relevant physical science content.

5) Appropriate physical science content should be introduced into current courses that deal with personal needs, societal problems and careers (e.g., social studies, home economics, industrial education and mathematics).

6) The courses so developed or modified should have many of the following characteristics if the above recommendations are to be fully realized:

   - Opportunities should be provided for students to pursue individual needs, goals, and interests (e.g., provision could be made for modularity, a project approach, or time periods for investigating individual topics).
   - Opportunities should be provided to apply science processes to real-world problems that have no pat solutions but require compromise and optimization.
   - Personal needs, societal issues and career preparation should be considered intrinsic to all facets of these science programs.
   - Basic concepts of physical science should be dealt with in the context of socially relevant problems.
   - Opportunities should be provided for students to interact with people working in science-related fields.
   - Opportunities should be provided for students to identify with persons of different lifestyles, socioeconomic status, ethnicity, and sex who are fully participating in the scientific enterprise.

- o Emphasis should be placed on the means by which scientific knowledge is generated.

- o Learning experiences should be provided which include laboratory experiences, out-of-school experiences, illustrations of different problem-solving styles, opportunities to look outward from a discipline to find understanding of its problems, exploratory activities that involve talking, guessing, and hypothesizing, and opportunities to participate in actual or simulated research.

Recommendation #3: Preservice and inservice teacher education programs should be developed which include emphasis upon personal needs, societal issues and career preparation, as well as the means by which these areas can be utilized as settings for applying, analyzing, synthesizing and evaluating fundamental knowledge in the physical sciences.

The synthesized results of the four studies clearly indicate that the teacher is the key to the educational process under consideration here. Goals can be changed and programs can be modified but their realization is dependent upon the teacher. One of the major means by which teachers are influenced is professional development programs. Teachers have positive feelings about science-related inservice programs and staff development activities. They express a need and desire to participate in such, especially those dealing with teaching approaches and the content of their specific field of science. Among the specific suggestions which elaborate upon this recommendation are the following:

1) Steps should be taken to increase the awareness of the need for expanded inservice education programs;

2) Incentives should be provided that will encourage teachers to participate in nationally and locally developed inservice education programs and staff development activities;

3) Inservice education programs should be developed which are locally relevant to the needs of the participating teachers and are designed to disseminate successful programs. Emphasis should be given to all of the goal clusters, to the higher levels of the cognitive domain, and the relevant physical science content;

4) Undergraduate science teacher education courses should be modified to include more emphasis upon all of the goal clusters and the means for attaining these goals for all students;

5) A resource utilization plan should be developed that will provide materials, ideas and other assistance to interested teachers upon request;

6) A major goal of these activities should be the internalization of a high value on physical science for all students and the pursuit of broad goals for instruction in this area.

Recommendation #4: Measures of desired outcomes pertaining to personal needs, societal issues, and career awareness should be introduced into the various tests of student achievement and broader district-level evaluation programs which will give to these goal clusters such emphasis as indicated by citizen and science groups through the established accountability mechanisms.

The standardized tests that are "imposed" upon teachers by their districts or other larger units have a major impact upon what teachers attempt to teach. Potentially, testing requirements are one of the major leverage points in bringing about change in the curriculum. Thus, it is recommended that attempts be made to influence the groups developing these instruments through awareness conferences, publications and development of sample exemplary instruments. In this regard, the role of the National Assessment of Educational Progress (NAEP) and professional societies is important. It is recommended that NAEP emphasize the personal needs, societal issues and career awareness goal clusters even more than they have in the past and that their "released" items be presented to school district personnel as models where appropriate. Thus, the specific recommendations are the following:

1) NAEP should be requested to give high priority to changing the emphasis within the science assessment to that indicated herein.

2) Awareness conferences should be conducted for district-level personnel who develop tests for their districts.

3) Banks of appropriate test items should be provided for school district personnel to draw upon in developing their local district accountability procedures.

4) Professional science teaching societies should be encouraged to develop or acquire appropriate item banks and encourage their use.

5) Established citizen-accountability groups should be informed of the need in question and encouraged to use their influence to assure that appropriate modifications to tests are made.

6) The National Science Teachers Association should be urged to hold item-writing (or selection) sessions for supervisors and other leaders at their annual conventions. Such sessions should focus upon "how to do" topics with respect to evaluation.

V. INQUIRY IN SCHOOL SCIENCE

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INTRODUCTION

For many years, the science education community has advocated the development of inquiry skills as an important outcome of science instruction. And for an equal number of years science educators have met with frustration and disappointment. In spite of new curricula, better trained teachers, and improved facilities and equipment, the optimistic expectations for students becoming inquirers have seldom been fulfilled.

A recent assessment of the status of science education in the United States brought this point home once again as many discrepancies were found between what is desired and what exists. But this time, rather than seek blame in poor teaching, unused facilities, or out-of-date curricula, we turned instead to the original statements of goals and expectations. We believe that the lists of desired student outcomes, including our own, contain sufficient shortcomings and limitations to justify a reconsideration of our expectations for inquiry learning.

In this part of the Synthesis monograph, we argue that such formulations have generally ignored the differences in human characteristics that affect people's abilities or desires to engage in inquiry activities. Further, these formulations have not considered the contextual realities in the schools and communities which affect the attainment of inquiry skills. We propose the more realistic view that not all students should be expected to attain competence in all inquiry outcomes. Such an expectation runs counter to what is known about student abilities and interests and ignores the influence of the school and community environment. In fact, for some students and in some environments it may be appropriate not to expect any inquiry-related outcomes at all! Thus, every student outcome with respect to inquiry in science education should be in agreement with individual differences, personal goals and environmental conditions.

The processes that led to this conclusion and its implications for science teachers are described in the remainder of this section of the monograph.

We consider inquiry to be a general process by which human beings seek information or understanding. Broadly conceived, inquiry is a way of thought. Scientific

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*Contributing authors and members of inquiry focus group also included: Glen S. Aikenhead (University of Saskatchewan); Leopold E. Klopfer (University of Pittsburgh); and James T. Robinson (Biological Sciences Curriculum Study). A slightly revised version of this chapter appeared in Science Education, January 1981.

inquiry, a subset of general inquiry, is concerned with the natural world and is guided by certain beliefs and assumptions.

Because the development of inquiry skills is one of the goals for science education, it was a natural focal topic for a study of science education carried out by a group of scholars under the auspices of Project Synthesis (Harms, 1977). The purpose of Project Synthesis was "to develop a set of concise statements and more lengthy reports identifying three sequential stages: (1) the desired outcomes of science education; (2) the current status of science education; and (3) the needs of science education and recommendations for meeting those needs." The tasks of analysis and synthesis were divided up according to five perspectives: physical and earth science, biology, inquiry, science/technology and society, and elementary school science.

Each topic was studied by a group of scholars. The task of the Inquiry Group was three-fold:

1) to specify the "desired state" for effective inquiry learning;

2) to determine the "actual status" by analyzing four recently completed status studies, Stake, et al (1978); Weiss (1978); Helgeson, et al (1977); and publications of the National Assessment of Educational Progress (NAEP) for the natural sciences (1977-78);

3) to compare the desired state with the actual status in order to identify needs and to recommend actions.

The members of this Inquiry Group were selected for their previous research and experience relevant to the task. Although several papers were provided for consideration during the first phase, the task was accomplished primarily by an analysis of the shared experiences of the inquiry group. The description of the desired states for student understanding of inquiry was greatly enhanced by the earlier writings of Klopfer (1971; 1976).

DESIRED STATE OF TEACHING SCIENCE AS INQUIRY

The domain of inquiry was divided into three main themes: 1) science process skills; 2) the nature of scientific inquiry; 3) general inquiry processes. Each of these three main themes has sub-categories, which are described in detail in the Synthesis Final Report (Harms and Kahl, et al, 1980).

Science process skills and general inquiry processes are essentially intellectual procedures. Within "general inquiry" are included strategies, such as problem-solving, uses of evidence, logical and analogical reasoning, clarification of values, decision-making, and safeguards and customs of inquiry. The latter include the agreed-upon procedures that individuals in all forms of rational inquiry are expected to follow.

Within the theme "science process skills" are included the usual range of science processes: observing and measuring; seeing problems and seeking solutions to them; interpreting data; generalizing; building, testing, and revising theoretical models.

The theme "nature of scientific inquiry" is concerned with the validity of knowledge. Here, the structure of scientific knowledge is tentative--the product of human efforts--affected by the processes used in its construction and by the social and psychological context in which the inquiry occurs. Scientific knowledge is also affected by assumptions about the natural world, such as causality, noncapriciousness and intelligibility.

To facilitate an analysis of the current status of science education, statements of the desired state were proposed. These statements are presented in three categories: context; transactions; and outcomes.

The contextual component is the set of pre-conditions existing prior to the exposure to learning. It includes such things as curriculum materials, trained teachers, science laboratories and community opinion. Context is the potential of the system to accomplish inquiry learning. A school that contains a well-equipped science laboratory and a highly trained teacher has a greater potential to accomplish inquiry learning than one which does not. Whether or not this potential is realized depends, in part, on the classroom transactions.

Transactions are the set of activities which expose the student to opportunities to learn. They are the actual interactions of the students with their teachers, other students, curriculum materials, the natural world and a host of other things. There is a kinetic characteristic of the transactions that distinguishes them from the context elements. Participating in hands-on experiences, viewing a film on the double-helix controversy, or reading about the philosophy of science are examples of transactions that would seem to facilitate inquiry learning.

Finally there are the outcomes of the schooling process. They are the results of transactions occurring in a certain context. A student's understanding of the tentative nature of scientific knowledge is one example of an inquiry outcome. A student's ability to interpret data represented in a graph is another example. Outcomes are usually measured by changes in student behavior, but it is likely that teachers, facilities, textbooks and other actors and props in the drama of learning are affected as well.

Context

The desired state for the context in which effective inquiry teaching occurs was summarized in terms of three groups: teacher characteristics, the classroom and the curriculum.

The teacher is the critical factor in achieving a desired state consistent with inquiry teaching. Effective teachers would value inquiry, would encourage an inquiry orientation in others, and would possess skills in enabling others to understand inquiry as a way of knowing. Such teachers take advantage of opportunities in their preservice and/or inservice experiences to conduct investigations, to develop an understanding of the history and philosophy of science, and to develop their competencies in inquiry teaching.

Inquiry classrooms have science objects and events that are obviously in use. Equipment and supplies are organized and available in such ways as to stimulate student investigations. The physical arrangement of the classroom is flexible enough to permit activities of various kinds without undue problems or loss of time.

Curricula include explicit statements of desired student outcomes that give attention to science process skills, the nature of scientific inquiry, and to attitudes and values. Science curricula that value these outcomes are available to all students, but statements of student outcomes and instruction should be carefully adjusted to the characteristics of the student population, including their needs and goals.

Transactions

Instruction in inquiry classrooms reflects a variety of methods—discussions, investigative laboratories, student-initiated inquiries, lectures, debates. Teachers serve as role models in debating issues, examining values, admitting error, and confronting areas of their own ignorance. The classroom atmosphere is conducive to inquiry. It is easy for students to ask questions. Risk-taking is encouraged and student comments are listened to, clarified, and deliberated with a high level of student-student interactions. Science content and processes are inseparable. "How do we know?" enters many conversations. Individuals, small groups, or the entire class move easily from discussion to laboratory or other "hands-on" activities. Classroom climates stimulate a thorough, thoughtful exploration of objects and events, rather than a need to finish the text.

Both formative and summative evaluation are integrated into the ongoing activities in the classroom. Techniques and instruments for summative evaluation are selected and used in such a way that student outcomes which reflect inquiry learning are assessed. With equal importance, formative evaluation procedures and instruments are deliberately chosen to gather data for course improvement.

Inquiry transactions are concerned with developing meaning. There is a time for doing. . . a time for reflection. . . a time for feeling. . . and a time for assessment.

Outcomes

As we developed student outcome statements we quickly realized that we could only present examples. We chose to weave together affective (feeling) statements, cognitive (knowing) statements and skill (doing) statements as exemplars within each category of student outcome statements. Each statement includes a parenthetical word to indicate its domain. A sample of the 128 student outcomes is presented to give the reader specific examples of our formulation of the desired state. The complete set is found in the Synthesis Final Report (Harms and Kahl, et al, 1980).

Four "goal clusters" were formulated by the Project Synthesis staff: personal needs, societal issues, fundamental knowledge, and career education and preparation. Student outcomes were specified within each of these goal clusters according to the three main themes of the domain of inquiry set forth at the beginning of this section. Table V-1 presents examples of desired student outcomes consistent with the point of view developed in the first phase of our study.

ACTUAL STATE

To determine the actual status of science education relevant to inquiry, we consulted four primary data sources. Three of these were conducted from 1976-1978 under the sponsorship of the National Science Foundation (NSF). One study, carried out at Ohio State University, was a 20-year literature review of pre-college science instruction, science teacher education, and needed assessment efforts (Helgeson, et al, 1977). A comprehensive national survey of science, mathematics, and social studies education in 1977 was conducted by the Research Triangle Institute in North Carolina (Weiss, et al, 1978). Eleven in-depth Case Studies in Science Education were reported by the University of Illinois (Stake and Easley, 1978). Our fourth source for current status data was the publications from the National Assessments of Educational Progress in Science between 1969 and 1977 (NAEP, 1977-78).

Our data sources were searched for indicators of the extent to which the context, transactions, and outcome elements suggested that science inquiry learning was occurring in the manner described in the preceding section. Each of the three NSF reports was carefully read and statements pertaining to inquiry, process, or scientific method were recorded. NAEP items which address elements of science processes were identified and added to the data gleaned from the reports. The resulting pool of information became the basis for our second report, a document portraying the current status of science inquiry learning in the United States (Harms and Kahl, et al, 1980). A summary of that report follows.

Context

In general, we found that although there was a positive attitude toward science expressed by those in charge of schools, no strong forces are working to promote science education. Science is not receiving a high priority by school superintendents (Stake and Easley, 1978, p. 19:10), state science requirements are diminishing (Helgeson, et al, 1977, p. 121), and there is some evidence that science education is being displaced by such emphases as "back-to-basics", career education and special education.

Because of its dependence on innovative curriculum, non-text materials, specialized facilities, and competent teachers, inquiry learning is especially sensitive to the level of support it receives. In many areas, money available for non-salary expenditures is dropping and the supporting climate for inquiry learning has disappeared. Information regarding the perceived importance of inquiry-related learning is contradictory. Inquiry-related goal statements exist at the local and state levels (Helgeson, et al, 1977, p. 160). Teachers and principals rank "information-

TABLE V-I:
A SAMPLE OF STUDENT OUTCOMES FROM A SET OF EXAMPLES OF STUDENT OUTCOMES DEFINING THE DESIRED STATES THAT REFLECT INQUIRY

GOAL CLUSTER I Personal Needs	GOAL CLUSTER II Societal Issues	GOAL CLUSTER III Fundamental Knowledge	GOAL CLUSTER IV Careers
Science Process Skills			
(Doing). Measures accurately such body symptoms as blood pressure, heartbeat, temperature, etc. that are important in monitoring one's health. (Knowing). Can judge the appropriateness of an hypothesis, tested to solve a personal problem, on the basis of data obtained, e.g., cost of gasoline and mileage rates.	(Knowing). Can measure personal actions that have influence on society, e.g., monitors through measuring techniques the heat loss of a home. (Doing). Interprets data presented about a societal problem and judges its implications for personal behavior, e.g., the effect of limiting speeds to 55 mph and resulting gas usage.	(Doing). Observes and describes objects and phenomena (including change) using appropriate language. (Attitude). Values data presented in the form of functional relationships, e.g., tables, graphs, equations.	(Doing). Participates in a variety of observational and measurement activities to sufficiently examine the potential and interest to them for a career in science. (Doing). Has experienced the successes and problems of interpreting data and forming generalizations to realistically consider careers in science.

Table V-1 (continued)

The Nature of Scientific Inquiry			
(Knowing). Deliberately recognizes that the relevance of scientific knowledge is likely to be limited to its own domain of inquiry (natural phenomena) and that other personal inquiries about one's life may not use scientific knowledge or scientific inquiry.	(Knowing). Anticipates that scientific knowledge related to societal issues may change and will therefore demand a different point of view in order to use the altered knowledge. (Doing). Extracts from a societal issue the component related to natural phenomena, identifying this component as being germane to scientific inquiry.	(Doing). Cites examples of earlier and current scientific explanations which have been, or are being, altered. (Knowing). Acknowledges that scientists deal with hypotheses, theories and models in terms of their usefulness (in explaining, predicting and encouraging growth in science) and not in terms of their absolute truth.	(Knowing). Recognizes the primary need to be curious about natural phenomena in order to be suitable for a science vocation. (Knowing). Recognizes that a career in science does not require a singular role, but is open to a number of different roles.
General Inquiry Processes			
(Doing). Uses evidence from a variety of sources to make decisions about personal health problems. (Attitude). Enjoys the challenge of refining problematic situations into solvable problems.	(Knowing). Can decide what are the main issues of a simple science-related social problem. (Doing). Decides what is and what is not scientific evidence in a simple science-related social issue.	(Knowing). Can grasp the meaning of simple scientific statements such that he or she would know what counts as evidence for and against it. (Example: knows that the statement "wood floats in water" implies that "wood is less dense than water.")	(Doing). Decides what the main issues of selecting a science career are. (Doing). Values open-mindedness in those who pursue scientific careers.

Table V-1 (concluded)

General Inquiry Processes (continued)		
(Knowing). Can ask questions to determine what the problem to be solved is. (Doing). Identifies the source of certain new evidence concerning the connection between smoking and lung cancer as the Tobacco Institute.	(Knowing). Acknowledges the desirability of considering various alternative viewpoints concerning science-related social issues. (Attitude). Enjoys identifying the evidence needed for decision-making about science-related social issues.	(Attitude). Voluntarily seeks the criticism of others on the data and interpretations of his/her experiments. (Doing). Never fails to report the complete set of observations in an investigation, rather than leaving out cases unfavorable to his/her hypothesis. (Attitude). Is committed to the necessity of accuracy in the work of scientists.

processing and decision-making skills" as very important (Helgeson et al, 1977, pp. 85, 179) and generally value first-hand learning (Stake and Easley, 1978, pp. 1:25, 10:12). However, at the state level, inquiry-related goal statements appeared in only eight states while eighteen states listed content-oriented goal statements (Helgeson, et al, 1977, p. 168).

There appears to be a discrepancy between existing general statements about the importance of inquiry and the attention given it in practice. Although teachers made positive statements about the value of inquiry, they often felt more responsibility for teaching facts (Stake and Easley, 1978, pp. 1:42, 12:5, 13:17, 19:5), "things which show up on tests" (Stake and Easley, 1978, p. 13:18), "basics", (Helgeson, et al, 1977, p. 9:3), structure (Stake and Easley, 1978, p. 12:9), and the work ethic (Stake and Easley, 1978, p. 12:9).

At the district and state levels, there is generally little support available from science curriculum specialists. Only 20 percent of the districts reported a full-time district coordinator or supervisor (Weiss, 1978, p. 39), and only 55 percent of the states had as many as one person working three-fourths time as a science supervisor (Weiss, 1978, p. 32).

A major problem in promoting inquiry was encountered in the preparation of science teachers. Many teachers are ill-prepared, in their own eyes and in the eyes of others, to guide students in inquiry learning (Stake and Easley, 1978, pp. 4:10, 12:4, 13:5; Helgeson, et al, 1977, pp. 82-83, Weiss, 1978, pp. 47, 142) and over one-third feel they receive inadequate support for such teaching (Weiss, 1978, p. B-106). Most teachers had not had adequate training for fruitful response to the observations or penetrating questions of a thoughtful student (Stake and Easley, 1978, p. 16:8). Their college science training was not likely to emphasize process skills (Helgeson, et al, 1977, p. 53) or research experience (Stake and Easley, 1978, p. 12:7). There have been some attempts to improve process skill development in teacher training programs (Helgeson, et al, 1977, p. 57), and about half of the practicing teachers in 1970 had attended NSF workshops (Helgeson, et al, 1977, p. 192). It is reasonable to expect that they have received some inquiry-oriented instruction in these workshops. There is evidence that inquiry training can result in significant changes in inquiry teaching methods (Helgeson, et al, 1977, p. 79) and that participation in designing inquiry lessons is more important than knowledge of science in the development of process teaching skills (Helgeson, et al, 1977, p. 66).

There was considerable evidence that teachers found inquiry approaches to be very difficult to manage (Stake and Easley, 1978, p. 18:68). In some cases, they consider state mandates for laboratory work impossible to meet (Stake and Easley, 1978, p. 1:81). About one-fifth of teachers surveyed considered equipment and supplies too difficult to get (Stake and Easley, 1978, pp. 16:37, 1:60). Others considered inquiry dangerous, especially in discipline-problem classrooms (Helgeson, et al, 1977, p. 166).

Another concern teachers expressed about inquiry teaching was that it didn't work for most students (Stake and Easley, 1978, p. 18:68). They see it as causing confusion (Stake and Easley, 1978, p. 1:64) and too difficult for any but the very brightest students (Stake and Easley, 1978, pp. 1:29, 1:92, 12:7).

It appears that many teachers and parents consider the primary purpose of science education to be preparation for the next level of schooling (Stake and Easley, 1978, p. 13:10). There seemed to be general agreement that "the next level", be it junior high, high school or college, would require preparation in "knowledge" rather than in inquiry skills. The knowledge nature of college entry exams (Stake and Easley, 1978, p. 4:8), the content of college courses (Stake and Easley, 1978, p. 13:1) and the intention of most students (70 percent) to go on to college (Stake and Easley, 1978, p. 18:106) all work together to convince parents, teachers and students that "next year" knowledge will be more highly valued than inquiry skills. This knowledge emphasis, combined with the absence of equipment and poor preparation of teachers for inquiry teaching, has perpetuated the traditional pattern of "assign, study, discuss, and test" pervading most classrooms. This mode of instruction is, of course, efficient if recall of facts and definitions is the major goal of instruction.

A final contextual factor is the considerable evidence that the press for "socialization" of students greatly affects classroom activities (Stake and Easley, 1978, p. 16:1). This goal leads to activities stressing authority and discipline, and for many teachers, inquiry teaching is inconsistent with these activities. It is difficult to urge open-mindedness on the one hand (inquiry) while at the same time demanding a consistent format in writing a lab report.

Transactions

Our search of the data sources yielded about two negative transactions for each positive one noted. That is, for each student activity that seemed likely to facilitate inquiry learning, we found two that were prohibitive. For example, although 30 percent of the nation's elementary schools are using the new NSF-supported curriculum materials, with their emphasis on inquiry skills, there are another 70 percent that are not (Helgeson, et al, 1977, p. 16).

Among teachers who have attended an NSF institute, 73 percent report using "hands on" materials in their classroom (Weiss, 1978, p. 107). Twelve percent of the elementary teachers, 32 percent of the junior high teachers, and 47 percent of the secondary teachers, have attended at least one institute (Weiss, 1978, p. 68). Many of these teachers are providing inquiry experience to their students but these teachers are in a minority, and most students are unlikely to be given opportunities to learn even the simplest process skills, much less the more involved aspects of scientific inquiry.

Some of our findings were encouraging and suggest some students and some teachers are actively involved in the science learning enterprise. Innovative curriculum materials are being used in 30 percent of the elementary schools and 60 percent of the secondary schools (Helgeson, et al, 1977, p. 16; Weiss, 1978, p. 80). About 50 percent of the students in grades 9 through 12 are enrolled in science (Welch, 1979) and more than half of the younger children report working on out-of-school science projects (NAEP C01X01). Science laboratories exist and are used in most of the nation's schools. The Weiss (1978) survey reported that 59 percent of the teachers involved the students with "hands-on" objects during their most recent science class (Weiss, 1978, p. 106). Several of the case study writers observed lessons where the students were encouraged to think for themselves (Stake and Easley, 1978, pp. 9:6, 4:10, 13:16, 3:103, 5:4, 9:7, and 3:101).

Unfortunately, for those who value inquiry, there are many instances of negative transactions. Our analysis yielded several general findings (Harms and Kahl, et al, 1980). Not much time in science classes is devoted to inquiring. Little science is taught in the elementary schools. When hands-on experiences are provided, they are not characterized by true problem-solving. The competing pressures on teachers (e.g., disciplining, basics, mainstreaming, integration, accountability) do not leave much time for learning inquiry skills. According to a report of a national survey, "We estimate the median to be about 10 percent time spent in inquiry teaching, still a lot higher than our field observers reported," (Stake and Easley, 1978, p. 16:31).

The case study reports are depressing as they conclude, "Science was something teachers took in college, but it was not something they experienced as a process of inquiry. It is not surprising then to find creative inquiry was not what we found in those eleven high school laboratories—except in rare circumstances," (Stake and Easley, 1978, p. 12:7). Inquiry teaching is a difficult and time-consuming task and teachers are not prepared for, or even sympathetic to, using it in their classrooms.

Outcomes

Most of the evidence regarding student outcomes was obtained from an analysis of the National Assessment of Educational Progress (NAEP) data for testing carried out in 1968-69, 1971-72, and 1976-77. It was during the last testing period that a larger share of attention was directed to measuring student competencies in the process of inquiry domain. Necessarily, our data sources are limited, but we believe the following conclusions to be justified based on the data available.

We found that students have been exposed, either in science class or in school or elsewhere, to many of the observing and measuring skills. However, when skilled performance or somewhat sophisticated application of observing and measuring skills is assessed, relatively few students are successful. For example, 82 percent of the thirteen-year-olds were able to read a thermometer accurately, but in measuring the volume of water in a graduated cylindar only 18 percent of the thirteen-year-olds made acceptable measurements. The seventeen-year-olds did somewhat better in this task, with 46 percent correctly measuring the volume of water (NAEP 204046).

In general, we found that students were able to correctly select a hypothesis to explain a phenomenon or to generate their own explanations when the phenomenon under observation was familiar. However, as the task became more distant from the common-world experience of the thirteen- and seventeen-year-olds, the success level dropped considerably.

A few teachers were observed in the case studies providing opportunities for involvement in the self-testing aspects of scientific inquiry. However, most teachers attended to values which would support the careful, productive conforming aspects of schooling and socialization. The values associated with speculative, critical thinking were often ignored and sometimes ridiculed. Students tended to express an unwillingness to change their ideas in light of new facts, even though most of them recognize this as an attribute of the working scientist. About half of the students see themselves as working for accuracy in checking school work. A few more expressed the notion that they would persevere in spite of problems.

Limited success was achieved on NAEP items which tended to "scratch the surface" of basic ideas about the nature of scientific inquiry. Examples include: (1) the importance of observations and theories; (b) the fact that solutions are sometimes not found to scientific problems; (c) the fact that changes are made in theories in light of new observations; and (d) the basis of science is empirical evidence.

However, the percentage of correct responses to NAEP items fell quickly as soon as the items did more than scratch the surface of basic ideas. For instance: (a) about 75 percent of the students recalled one major aim of science, but only half could distinguish between the aim of science and the aim of technology; (b) while over 70 percent understood the importance of observations, less than half knew about errors inherent in the measurement process; (c) while 80 percent understood that scientific models are used for predicting, less than 50 percent could recognize an important quality of scientific models; (d) most seventeen-year-olds knew that scientists publish their results, whereas less than 60 percent of these older students realized that the scientists' work is founded upon specific assumptions; (e) while a sizable majority of youngsters attested to the importance of experiments to science, only 40 percent to 60 percent understood the importance of controlling all variables in those experiments; (f) while 70 percent to 80 percent of all students felt that theories change, only 25 percent to 32 percent of the nine and thirteen-year-olds realized that all scientific topics are not thoroughly understood. About half of the students believed that a scientist should be critical of the work of other scientists and should be open-minded with respect to theories. When these characteristics were applied to the students' own situations their expression of these safeguards and customs was considerably less favorable.

In conclusion, it seems fair to say that although there was an occasional glimmer of knowledge about the processes and nature of scientific inquiry, in-depth understanding was not generally exhibited. Students learned about science but seemed to perceive it as something done by somebody else rather than something that could be incorporated into one's own way of thinking. They knew that scientists are likely to examine their conclusions and change them in the light of new evidence. The students seem much less willing to apply that characteristic to problems they themselves encounter.

DISCREPANCIES BETWEEN DESIRED AND ACTUAL STATES: DILEMMAS AND ALTERNATIVES

Discrepancies

A point-by-point comparison between the desired state for inquiry learning and the actual status yielded many discrepancies. Strong, widespread support of inquiry is more simulated than real. A major barrier to teacher support of inquiry is its perceived difficulty. There is confusion over the meaning of inquiry in the classroom. There is concern about discipline. There is a worry about adequately preparing children for the next level of education. There are problems associated with a teacher's allegiance to teaching facts and to following the role models of the college professors.

The activities which inaugurate and sustain the teaching of scientific inquiry are conspicuously absent in most schools. A desired degree of inquiry instruction is rare. One finds encouraging evidence in the presence of lab facilities and materials, some hands-on activities, teachers graduating from NSF workshops, and NSF-sponsored curricula. However, it is difficult to observe the assumed effect these innovations have on classroom practice.

In regard to context, the Case Study data suggest that: 1) the community resists inquiry into values; 2) the teacher's use of authority in science classrooms discourages problem solving, decision making and scientific inquiry; and 3) the customs of inquiry tend not to be in evidence in science classes. These results help to explain why customs of inquiry are valued by only a small percentage of students, though most of these same youngsters recognize the necessity of these customs for scientists.

In all cases of student outcomes, achievement increased with the age of the child, from nine-year-olds to seventeen-year-olds. The status of inquiry teaching in the schools does not encourage one to conclude that science instruction causes the observed increase in student achievement. On the contrary, there are several credible explanations independent of classroom instruction. These include: intellectual maturation, an increase in "test-wiseness", a sample bias due to drop-outs, an increase in reading ability, and the experiences which children gain at home and in their communities.

Dilemmas and Alternatives

Because of the widespread discrepancies summarized above, we have reached the unavoidable conclusion that the desired state for inquiry in science education is not being achieved. Not only is the desired state not being achieved in general, but there are a number of specific instances where the observed current status represents a particularly poor showing.

Those who value the teaching of scientific inquiry may find themselves in a dilemma over this conclusion. There has been an emphasis on inquiry by the leaders in science education, especially during the past 20 years. Curriculum reform and teacher education have received much attention in this regard. In fact, many educational leaders expected the new curricula and the revised teacher preparation programs to have demonstrable impact on classroom practice and student achievement. However, the results of our study show that these expectations are not being realized. The time has come for the science education community to re-analyze and re-evaluate its expectations.

What are some reasonable implications of the discrepancy problem? We seriously considered five possible solutions. The details of our deliberations are not recorded here. Instead a summary of the first four solutions is offered. This is followed by an in-depth analysis of a fifth solution which we propose for serious consideration.

One response to the problem could be to reorganize the singular occurrences of excellence which do exist and the instances of achievement in inquiry that have been documented. Thus, one could decide to change nothing and be satisfied with the current status of inquiry learning in science education. We lend no support to this "do-nothing" approach.

A second alternative, often found in the literature or in keynote addresses, calls for a rejuvenated attempt at improving inquiry instruction: calling for more teacher education, better science supervision, more money for materials, more curriculum development, further changes in university science courses, and better tests. However, as the data show, the total context needed to support this enhancement of inquiry instruction is resistant to change. Calling for rejuvenation of inquiry instruction amounts to tinkering with the established system. Although we appreciate the usefulness of such actions, we recognize the discouragingly small success such tinkering has had in the past, and we reject this popular approach as a workable solution.

A third alternative calls for a reformulation of our inquiry outcomes in order that most students can achieve them. In other words, we would rewrite our desired outcomes to better match the current status. However, if we diluted our notion of scientific inquiry to that extent, we would simply be subscribing to mediocrity in U.S. schools. We cannot support this course of action.

But, if we abandon inquiry instruction altogether, as the evidence tends to suggest we should and as we seriously considered doing, then we run the high risk of being irresponsible and insensitive to the needs of some youngsters who will obviously need this knowledge in order to cope with, and help others to cope with, their world of 2001 (only one generation away). We reject this defeatist alternative as well.

Finally, a fifth alternative emerged quite unexpectedly. It requires a reformation of our traditional views about teaching scientific inquiry in schools. This new viewpoint addresses the causes for the current lack of inquiry instruction, but at the same time, it maintains our desired outcomes of scientific inquiry instruction. We support this alternative over the four other courses of action and inaction.

A Recommendation

Numerous statements of desired student outcomes with respect to inquiry in science education have been formulated over the years by educators, philosophers, natural and behavioral scientists, and other well-intentioned thinkers. However, no previous formulations have taken into account two important factors: 1) the diversities in human characteristics that affect inquiry-related behaviors; 2) the contextual realities of the nation's diverse schools and communities. The following proposal urges that attention be given to these two important factors. The educational era is at hand where the matching of learning experiences to the traits and needs of the individual has become feasible. In addition, it is essential to look at the climate for promoting inquiry in a school, which may be favorable, indifferent, or antagonistic.

We propose the following general framework for defining expected inquiry outcomes. The framework applies to outcomes in all three subdivisions of the inquiry domain, (i.e., science process skills, the nature of scientific inquiry and general inquiry processes). On the assumption that it is senseless to assert an outcome goal if relevant, reliable knowledge informs us that it is unattainable, we propose that:

> EVERY EXPECTED STUDENT OUTCOME WITH RESPECT TO INQUIRY IN SCIENCE EDUCATION SHOULD BE RESPONSIVE TO INDIVIDUAL DIFFERENCES, PERSONAL GOALS AND COMMUNITY WISHES.

The key ideas in this general proposition deserve explanation. By being responsive to individual differences for an expected inquiry outcome, we mean that fulfilling it does not demand a behavior or activity which the student's developmental, intellectual, and/or personality characteristics do not allow him or her to perform. A quick way to get to the heart of this idea is by a metaphor concerning athletics. Youngsters are not expected to perform as well in baseball, for example, as adults are. Developmental differences are taken into account when setting expectations. Again, some racers, but not all, have the potential to run a mile in less than four minutes. Differences among individuals in their capacity or ability to perform particular tasks are recognized. Also, some swimmers are better suited to short races, others to endurance races. Assuming approximately equivalent swimming skills and capacities, such different preferences probably are due to personality differences and are accepted. Our point is that, just as differences in development, ability and personality are recognized in setting performance expectations in athletics, the same kinds of differences should be taken into account when designating expected outcomes in the domain of inquiry. Harold Benjamin warned us long ago in The Saber-Tooth Curriculum about the folly of setting the same performance expectations for all students, regardless of whether or not they could perform the tasks.

When we say that an expected inquiry outcome should be responsive to personal goals, we mean that attaining the outcome does not require the student to become competent in a behavior or activity which is incompatible with his or her long-term personal goals. The personal goals include both the student's choice of career direction, with its appropriate level of education, and his or her roles as a functioning adult in society. The notion that education should contribute to the students' attainment of these types of personal goals is hardly new, nor is the notion that students' science learning experiences should carry their just share of the load in this regard. Goals for occupations and careers vary widely. For certain of these occupations and careers, a broad range of competencies from the inquiry domain is necessary. For others, selected inquiry domain competencies are appropriate. For still others, including all those occupations toward which probably the majority of elementary and secondary school students are headed, many of the inquiry domain competencies cherished by science educators are unnecessary, inappropriate or incompatible. We suggest that it is futile to ask students to develop any such competencies.

A metaphor concerning dramatics may serve to illuminate this aspect of our proposal. Almost every person has the opportunity to be in the theater (or movie or television) audience as a consumer of drama. As such, the person should appreciate drama and have some degree of understanding of its form of communication. Similarly, almost everyone can read a play or drama review, and this vicarious participation also calls only for an appreciation and a limited understanding of drama. But, some people (including children) act in plays as amateurs, and they necessarily have some knowledge of the craft of drama, the depth of their knowledge depending on the extent of their exposure. Also, a few people act professionally and perform drama regularly, understanding it well. Finally, there is a small group of professionals, who are playwrights, and these are the creators of new ideas in drama. In this dramatic arts metaphor, clearly the level and type of competence expected of a person is compatible with the person's role in relation to drama. The level and nature of competence expected of a professional actor is vastly different from the competence expected of a member of the theater audience. So, too, with respect to science, where there are nearly exact parallels with each of the roles and relationships described for drama. For example, the level and nature of competence expected in process skills must be conditioned by the personal goal the student has in terms of his or her adult social role and occupation.

We also have called for responsiveness to community wishes in defining outcomes. This simply means that an expected outcome in the inquiry domain is acceptable if it does not demand a student behavior or activity which environmental conditions in a school or community do not allow. The requirement of community sensitivity recognizes the well-documented differences among schools regarding the possibilities they afford for promoting inquiry. For example, when the emphasis in a particular school is on "basics" and a strictly factual treatment of science is wanted, little possibility for inquiry exists in that environment. There are many schools, of course, where the climate for inquiry is considerably more favorable. Setting expectations for many inquiry outcomes in the first kind of school would be foolish and dishonest, but in the second instance, inquiry outcomes would seem attainable.

The requirements we are proposing for expected inquiry outcomes deliberately restrict the inquiry-related outcomes to be expected from students with particular psychological characteristics, in specified occupational-goal groups, and in particular schools. We believe that these restrictions are both sensible and necessary at the present time. A consequence of these requirements which should not be missed, however, is that they mandate expanding the expected inquiry domain outcomes for some students, groups and schools. For example, for academically gifted students, the requirement of individual differences would recommend more extensive expectations than have been customary regarding inquiry outcomes. The requirement that the expectations be compatible with the personal goals of students would direct future scientists to a heavier dosage of expected competencies in designing and analyzing experiments, and it would require prospective politicians to acquire increased knowledge competencies concerning the nature of scientific inquiry and the interrelationships of science, technology and society.

Another point which we wish to make explicit is that, within the general framework of reasonable restrictions (and, sometimes, expansions) on expected outcomes, we still believe in the validity of the arguments for incorporating inquiry-related outcomes and methodologies in science teaching. What we know has been wrong in the past was the unthinking assertion that all inquiry outcomes were appropriate for all students in all situations, and we have proposed a way that could be changed. But, with regard to the content of science courses, we still agree that not only knowledge of the products of scientific inquiry, but also the development of skill in certain processes of scientific inquiry is important for many students. We also still believe that some items of knowledge regarding the nature of scientific inquiry should be a part of the conceptual baggage of all educated citizens. And, we still believe that an important purpose of schooling is the development of general inquiry behaviors, which include problem solving, decision making, and values clarification. However, science education cannot alone be responsible for fulfilling this purpose. If developing problem-solving abilities is viewed as an important goal in a given school, techniques and procedures for developing these abilities should be present in several curricular areas. Moreover, science education has responsibilities other than developing problem-solving abilities. Instruction in the key concepts of science is another important obligation.

Providing Inquiry-Related Education Experience

The preceding section described the desired state for inquiry outcomes emphasizing that expected competencies be tailored to individual student and community characteristics. We next propose some mechanisms which can provide the appropriate inquiry-related experiences. The plan to be described represents a kind of general model that could be adapted to various educational objectives. The model is especially apt for the inquiry domain because it offers a very large range of legitimate variations in outcomes for different individuals. (If the domain were learning to read English text, for example, the range of legitimate individual variations in outcomes would not be nearly so large, and applying the model might not be especially useful.)

Central to the model is a Student Profile for Inquiry Competencies, which is set up and maintained for every student and periodically updated. This Profile has a goals component and a programmatic component. The goals component contains an inventory of those inquiry-related competencies which the individual is expected to develop throughout his or her years in school. The inventory contains competencies in all three subdivisions of the inquiry domain, and the process of designating the student's expected competencies takes account of the requirements discussed above. In essence, the goals component of the Profile is the individual's scope and sequence charts. It gives direction to the student's learning program.

The programmatic component of the Profile lists the kinds of experiences that will develop the designated inquiry-related competencies of the student. It lays out specific actions the student should take during his or her time in school. These actions include various instructional procedures and materials which are familiar to science teachers. Some of these are:

- semester or year-long courses with emphasis on promoting inquiry;
- self-instructional modules which develop specific inquiry-related skills or knowledge;
- minicourses which do the same;
- laboratory and field investigations with varying degrees of structure and varying opportunity for discovery;
- textbooks and other reading materials with varying opportunities for developing specific inquiry-related competencies;
- assessment instruments to measure and diagnose progress in developing those inquiry competencies appropriate for the individual.

Each student's learning program for the inquiry domain is designed on the basis of these and other possibilities for actions that match different competencies.

The model we are describing, with its individual Student Profiles for Inquiry Competencies, has several implications for implementation. First, it is necessary to make available to students a considerable variety of instructional materials, some that develop specific inquiry-related competencies and some that do not. Moreover, sufficient attention needs to be given to systems for managing students in small groups, in independent study and in large groups. Finally, there appears to be no urgent need now to design new approaches nor to develop new materials that help students attain inquiry competencies. A goodly array of approaches and materials already exists that can accomplish most of the desired outcomes. The real challenge is to structure existing materials and techniques in effective ways suitable to each learning situation.

In summary, we have proposed that science teachers and educators must attend to the uniqueness of the individual and to the contextual differences in schools. We believe that this evidence is so compelling that it warrants the construction of plans to provide opportunities tailored to the particular characteristics and goals of individuals. These individually tailored plans also must take account of the expectations and possibilities in the student's particular school environment. By this mechanism, societal goals with respect to science learning which find expression in community and school expectations can become meshed with the individual and personal goals of the student.

We are convinced that, in the present educational era, it is technically feasible to match each student's learning experiences to individual traits and needs. Planning for this kind of matching in the inquiry domain is particularly apt, because there are large variations in desirable inquiry-related outcomes for different students. Our stance is that all students should not be expected to attain competence in all inquiry-related outcomes which science educators (including ourselves) have advocated in the past. For some students and in some school environments, it may be appropriate not to expect any inquiry-related outcomes at all.

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VI. SCIENCE EDUCATION IN THE ELEMENTARY SCHOOL

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INTRODUCTION

"Young children are naturally curious about the universe and are continuously exploring their immediate environment. During these early years they form their basic attitudes, patterns of thought, and modes of behavior. It is, therefore, during these years that particular attention must be given to establishing the attitudes and modes of inquiry that are associated with the scientific enterprise—its processes and content," (American Association for the Advancement of Science, "Science Teaching in Elementary and Junior High Schools." Science. Vol. 133, No. 3469, 1961). This quote is from a 1961 article in Science describing three conferences organized by the AAAS to make recommendations for the future of elementary school science. It heralded the beginning of fifteen years and millions of dollars of activities to improve the teaching of science in the elementary school.

From a curriculum diet of sameness and uniformity in the early 1960's, elementary science moved in the late 1970's to a state that reflected a wide diversity of goals, philosophies and types of materials. The completion of the three major NSF projects in elementary science (ESS, SCIS, SAPA), the publication of several "new generations" of elementary science textbook series (which have all apparently been influenced by the NSF projects), and the continued publication of textbook series that have been in existence for many years provide a wide variety of materials. These materials vary considerably in intended student outcomes, learning/teaching styles, cost, format and content. NSF's investment in curriculum development in the last fifteen years has resulted in the production of many resources available to the elementary schools in this country. Far from producing a "national" curriculum the result has been to insure that there will be no such single approach. An examination of the textbooks of the early sixties would reveal a near "de facto" national curriculum because of the consistency of content from series to series. Today the opposite is true.

A review of the three NSF research studies reveals a not so encouraging picture in the schools. A composite scenario that represents the great majority of elementary classrooms will summarize much of the more quantified data detailed in the following sections.

The typical elementary science experience of most students is at best very limited. Most often science is taught at the end of the day, if there is time, by a teacher who has little interest, experience or training to teach science. Although some limited equipment is available, it usually remains unused. The lesson will

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probably come from a textbook selected by a committee of teachers at the school or from teacher-prepared worksheets. It will consist of reading and memorizing some science facts related to a concept too abstract to be well understood by the student but selected because it is "in the book."

A dim view? Maybe, but one substantiated by all three of the NSF studies. What if our representative teacher wants to change and update science teaching? Chances are two out of three that no one is designated in the school or school district to provide any suggestions or new techniques or materials. Unless the teacher is one of the 10 to 30 percent who have heard of the NSF-developed curricula, he/she will not even know they exist. If he/she does by chance know about one of the programs and decides to try it, funds may be so limited that the equipment required to support the program cannot be purchased. Furthermore, the pressure of the administration and parents to return to a greater emphasis on the basic skills and discipline gives little incentive to make any greater efforts to teach science.

The effect of the "back-to-basics" emphasis is but one example of ways in which this pressure exists. The teaching of elementary science is not so well established that it can exist independent of the influences of the school patrons, the administration, changing enrollments, budget decisions, or teacher interests and professional preparation. None of these elements directly prevents the teaching of elementary science. But, in the days of more demanding priorities, each of these contextual factors often results in a reduction in the quality of the science being taught. It might be said that "nothing works directly against the teaching of science in the elementary schools--but, unfortunately, neither is anything working to enable it to exist."

THE DESIRED STATE OF SCIENCE IN THE ELEMENTARY SCHOOL

The wide range of goal options and materials available to elementary science teachers today required Project Synthesis to first establish a "desired state" of elementary science education.

Student Outcomes

The desired student outcomes were written based upon knowledge of students and their needs and were not written with any particular program in mind. They were based upon the research on and knowledge of how young children learn at their unique stage of mental development. It was decided that the content knowledge described in the desired state should not be a specific list of concepts or facts but should broadly sample all content areas, support all four goal clusters, develop the processes of science, and be of interest to students. In developing the rather broad statements of student outcomes in the four goal clusters, we reviewed the more detailed outcome statements from the secondary groups (physical/earth science, biology, science/technology and society interactions) to see if they fit within the elementary outcome statements. In virtually every case they did. The elementary school was not viewed as the place to begin the development of detailed concepts in preparation for junior and senior high school. Instead, it is the place to excite students' curiosity, build their interest in their world and themselves and provide them with opportunities to practice the methods of science. Such a program can be made conceptually rich by introducing exciting and important phenomena to be observed and analyzed, but it should not reflect a need to cover a syllabus of content in all science disciplines.

With these assumptions in mind, the following student outcomes were considered desirable in the four major goal clusters.

Goal Cluster I: Personal Needs

Students will:

- Be able to exhibit effective consumer behavior. This requires the skills to evaluate the quality of products, the accuracy of advertising and the personal needs for the product.
- Use effective personal health practices.
- Have knowledge of one's self, both personal and physical.
- Possess a variety of skills and procedures to gather knowledge for personal use.
- Be able to learn when presented with new ideas and data.
- Use information and values to make rational decisions and evaluate the personal consequences.
- Recognize that their lives influence their environment and are influenced by it.
- Recognize and accept the ways in which each individual is unique.
- Be aware of the constant changes in themselves.

Goal Cluster II: Societal Issues

Students will:

- Recognize that the solution to one problem can create new problems.
- Use information and values to make decisions and evaluate the consequences for others in their community.
- Recognize that some data can be interpreted differently by different people depending on their values and experience.

- Recognize the ways science and technology have changed their lives in the past by changing the coping skills available to them.

- Possess a sense of custodianship (collective responsibility for the environment over a period of time).

- Recognize that science will not provide "magic" solutions or easy answers—instead, the use of hard work and the processes of science are required to "resolve" rather than "solve" many problems.

Goal Cluster III: Academic Preparation

Students will:

- Develop an understanding of information and concepts from a wide variety of topics selected from the life, earth and physical sciences. There is no one set of basic topics for elementary science instruction.

  - This variety of topics may be used to help develop the skills in generating, categorizing, quantifying and interpreting information from an environment.

  - This variety of topics may be used for the sole reason that they are interesting to students at a particular age.

Goal Cluster IV: Career Education/Awareness

Students will:

- Recognize that scientists and technicians are people with personal and human characteristics. (Teachers should use biographical sketches, personal kowledge, etc.)

- Observe both sexes, minorities and handicapped represented in the written materials to encourage equal access to science-related careers.

Program Characteristics

Program characteristics which are viewed as desirable to produce student outcomes outlined above include:

- Genuine alternatives should exist so that real decisions can be made, real problems solved, and the consequences known or experienced.

The problems presented to students should be definable, possible to accomplish, and should grow out of first-hand experience.

- Students should be actively involved in gathering data.
- Information that is presented should be clearly articulated through alternative modes; i.e., books, films, "hands-on" experience, etc.
- Information transmitted should be as appropriate as possible for the age level of the student and reflect how it was developed.
- Science programs should be interdisciplinary in nature (involving areas other than science).

Program Implementation

The desired characteristics of program implementation include the following components:

For Whom?

All children should have equal access to science instructional resources (programs, people, materials and time).

By Whom?

The teachers responsible for elementary science instruction should have the following competencies or characteristics:

- Sufficient knowledge and experience in science content and processes to feel confident when working with students.
- An understanding of the developing nature of the elementary student's mental, moral and physical capacities and the role that elementary science can play in enhancing their development.
- A demonstrated ability to use (and know the results of) appropriate teaching strategies, i.e., grouping of students, questioning strategies, inquiry techniques, evaluation procedures, etc.

In What Way?--(Instruction)

- Instruction should be congruent with the desired outcomes and program characteristics above.
- Instruction should reflect the aptitude and characteristics of students and teachers.
- Policy should allow for an adequate amount of time committed to science to enable students to achieve the expected outcomes.

- o The actual time spent in instruction should be consistent with the policy.
- o The teacher's planning and interactive skills should facilitate and emphasize cooperative interaction between students without eliminating appropriate competition and individualistic interaction.
- o Instructional strategies should help students learn to ask good questions, argue productively, evaluate their own work; such strategies include effective questioning behavior, neutral rewarding, encouraging of controversy, etc.
- o Because language grows in the context of experience, so the language of science needs to be learned in the context of experience with science.

Facilities

- o The availability and maintenance of facilities (equipment, media and supplies) should be adequate to support the program requirements.
- o Enough concrete materials should be available to allow individuals or small groups to each have a set.
- o An effective system should exist for getting appropriate materials to teachers, collecting them afterward, and replenishing missing materials for the next use.
- o A system should exist to provide materials not mentioned in the curriculum but of interest to specific teachers and/or groups of students.
- o A setting should be maintained which allows for flexible seating arrangements and provision of needed resources (water, fresh air, etc.).
- o A setting should be maintained that allows for display of science activities, storage of materials and incompleted pr s, and interest centers related to science topics under stud

ACTUAL STATE OF SCIENCE IN THE ELEMENTARY SCHOOL

Review of Textbook and Programs

Recognizing that textbooks and other published science curriculum materials represent the major determinants of the student outcomes in elementary science (Stake and Easley, 1978, p. 13:5; Weiss, 1978, p. 88), a review was made of three categories of published materials.

Category A

Based on the national survey of current practices in science instruction by Weiss (1977), the four most frequently used text series at that time were selected for review. The Weiss study concluded that these four text series collectively comprise 22 percent of the curriculum in the primary classrooms and 40 percent of the curriculum in the intermediate classrooms. These series were Concepts in Science (Brandwein), Science: Understanding Your Environment (Mallinson), New Ludlow Science Program (Smith), and Today's Basic Science Series (Navarra).

Category B

According to the Weiss survey, three of the curriculum programs funded by the National Science Foundation are currently being used in at least eight percent of the classrooms. These programs were: Elementary Science Study, Science Curriculum Improvement Study, and Science - A Process Approach.

Category C

Four additional text series were also reviewed since it was felt that this "new generation" of text represents a third potential pool of influence on science classrooms. The four text series in the category were: Ginn Science Program (Atkin); Elementary School Science (Rockcastle); Modular Activities Program in Science (Berger, et al); Elementary Science: Learning by Investigating (ESLI).

Each of the categories of curriculum materials was compared with the established desired states in the four goal clusters, and the results summarized in Exhibit VI-A.

An examination of Exhibit VI-A indicates that no single program or category provides material equally well in all four goal clusters; but what should be noted is that by selecting materials from more than one series or category virtually all sub-goals of all the goal clusters can be met. Materials are available which match the expectations of the desired state.

EXHIBIT VI-A
Congruence of Elementary Texts
With Project Synthesis "Desired" Characteristics

Goal Cluster I: Personal Needs

	Sub-Goal	A Frequently Used Texts	B NSF Texts	C New Generation Texts
1.	Consumer Behavior	None	None	None
2.	Personal Health Practices	Good to Fair	Low	High to Good

3.	Personal Health Information	High to Good	Low	High to Good
4.	Skills in Gathering Knowledge	None	High	High to None
5.	Ability to Change	None	High	Low to None
6.	Decision-Making	None	Good	Low to None
7.	Environmental Influence	None	Low	High to Good
8.	Individual as Unique	None	Low	High to Good
9.	Change in Themselves	None	Low	High to Good

Goal Cluster II: Societal Issues

	Sub-Goal	Frequently Used Texts	NSF Texts	New Generation Texts
1.	Solutions Can Create New Problems	None	Slight	None
2.	Decision-Making and Community Consequences	None	Good in SCIS	Slight
3.	Alternate Data Interpretation	None	Good	Good in some instances
4.	Ways Science Changes Lifestyles	None	Very Slight	Some
5.	Sense of Custodianship	None	Very Slight	Good in some instances
6.	Science is not Instant "Magic"	None	Very Slight	Good in some instances

Goal Cluster III: Academic Preparation

	Sub-Goal	Frequently Used Texts	NSF Texts	New Generation Texts
1.	Skill Development Emphasis	None	High	High to Low based on programs
2.	Variety Based on Student Interest	None	High to Low based on programs	High to Low based on programs

Goal Cluster IV: Career Education/Awareness

	Sub-Goal	Frequently Used Texts	NSF Texts	New Generation Texts
1.	Human Side of Scientists	Some Biography	Little to None	Good in One Series. Little to None in Others
2.	Minority Access	Little	None*	Little

*These materials are extremely neutral with respect to sex and race since students do not have access to printed materials or photographs of students or adults.

Review of NAEP Data

The National Assessment of Educational Progress data, both on affective and cognitive outcomes, were reviewed from the perspectives of the four goal clusters.

Goal Cluster I: Personal Needs

NAEP data from nine-year-olds on health-related topics indicated approximately 50 percent recognized the function of major systems in their bodies (C15C01) and 73 percent understood what would make the heart beat slowest (C1504). A larger percentage of the students could distinguish between inherited and learned behaviors (C18C04) and draw a comparison between the uses of the senses in deaf and blind persons (C56C03). Fewer students (35 percent) seemed to have an understanding of how to stop a badly bleeding cut (C71C14) or knew what causes them to hear a friend when he/she talks (C24C05). Most nine-year-olds understand situations requiring that one see a doctor (C71C01), and 93 percent say they would stay home from a party when they have colds (C02A07).

Responses given regarding nutrition revealed 78 percent of the nine-year-olds selected a balanced menu on the first or second choices (C71C11), and 95 percent had knowledge of the kinds of things one eats to maintain good health (C71C13). Seventy-three percent incorrectly concluded that protein provides quick energy (C15C05).

Questions asked about safety and danger showed varying levels of understanding: 30 to 96 percent in the uses of electricity (C25C12); 44 to 87 percent in the uses of equipment, chemicals and the importance of reading labels (C71C04), and 49 to 77 percent about listening to loud sounds (C24C06).

Information produced by scientific research was recognized as being useful for keeping healthy by 91 percent, for deciding what cereal to buy by 50 percent and for choosing a toothpaste by 53 percent of the nine-year-olds (C01002).

The subjects covered by the items cited here mostly fall into the sub-goals #1, Personal Health Practices and #2 Personal Health Information which are well represented in the most widely used textbooks. This probably accounts for the generally successful performance of students on these items.

Goal Cluster II: Societal Issues

The NAEP cognitive and affective results revealed some of the knowledge and attitudes that young students have regarding social issues. A large majority of the nine-year-olds believed that pollution, energy wastes and disease were serious problems and that they could do something about them (C02A05, C02A06). Approximately 90 percent of the nine-year-olds knew about simple acts that help or hurt the environment (C62C11). Fairly large percentages (80 to 90 percent) of the nine-year-olds were willing to do something, even if it was inconvenient, to improve the environment.

On several exercises for which inferences and/or simple reasoning were required to consider the consequences of a decision, nine- and thirteen-year-olds demonstrated limited success. Only 23 percent of the thirteen-year-olds knew that a long-range consequence of use of fossil fuels was that they would be used up (C63C06). When asked the consequences of stopping the use of insecticides, only 16 percent of the thirteen-year-olds could infer that it would cause more people to starve (C62C01). When thirteen-year-olds were asked to identify the results of eliminating a disease, 45 percent indicated it would increase the population, 37 percent indicated that it would increase food consumption, 31 percent indicated that it would reduce the reserves of natural resources and 38 percent recognizd it would produce a greater need for recreation. These results are disappointing.

Goal Cluster III: Academic Preparation

In the discussion of scientific knowledge, four basic skills were defined as being essential. In the skill of generating information or observing most students (82 percent of nine-year-olds) can order a sequence of simple events in a change (C56C04). Sixty-eight percent of the nine-year-olds can recognize differences in information from people with different handicaps (C56C03). A high percentage (53 percent) would do an experiment to find out the answer rather than ask the teacher (C52C01). Ninety-one percent of nine-year-olds can read a grid map, but few (30 percent) can describe change in location based on a map (C54C10, C54C11).

When it comes to categorizing observations or classifying, most thirteen-year-olds (66 percent) can use a classification scheme (C55C01). Few nine-year-olds (26 percent) can generate categories of classifications when given the objects (C55C04).

In quantifying observations or measuring, many nine- and thirteen-year-olds have taken measurements many times in solving problems outside of class (C04A04). About two-fifths of nine-year-olds and more than one half of thirteen-year-olds can accurately estimate the length of an object in metric units (C54C01, C54C08, C54C12). Ninety-three percent of nine-year-olds can read a thermometer correctly (C54C13).

In the skill of interpreting observations, few (31 percent of nine-year-olds) recognize regularity in nature; e.g., phases of moon (C52C03). Generally students can construct interpretations based on concrete experiences, but this is not so with second-hand information. Generally, most thirteen-year-olds can read graphs and tables, but fewer can successfully interpret graphs (especially line graphs).

Goal Cluster IV: Career Education/Awareness

Do students want to go into science as a career? The nine-year-olds were positive about science as a career. Sixty-nine percent felt it would make them important, and 64 percent said it would be fun. About one-fourth of the nine-year-olds, however, were already feeling negative about this career choice with 27 percent feeling it would be too much work, and 20 percent feeling it would be boring (RC02A08). By age 13, the positive feelings had decayed to the point where less than half thought science as a career would be fun (49 percent). Only 42 percent felt a caree[illegible] science would not take too much education and half felt it would not be too m[illegible]k (RC02A03).

In terms of recognizing scientists and technicians as people with personal and human characteristics, there were almost no data available for the nine-year-olds other than only 14 percent saw science as a "lonely" profession (RC02A08). Even with the relatively low interest of the thirteen-year-olds in science as a career (less than 50 percent wanted to know more about science as a career), 81 percent would like to see scientists in action (RC02A01), perhaps indicating an interest in scientists as people.

There were data available on group differences in achievement and attitudes toward science as a career. Even at age nine, boys felt more positive and were more interested in science-related careers than girls and had higher achievement. There was more of a discrepancy in favor of males in attitudes and achievement by age thirteen.

At age nine, black students were less enthusiastic about careers in science than white students and showed poorer achievement. Black nine-year-old students were much less likely to think science was useful outside of school than white students--57 percent of black students, compared to 74 percent of white students (RC01U03). However, by age 17, black students generally felt more positive about science than white students though still lagging behind white students in achievement.

Interestingly enough, advantaged urban students at age 13 were less convinced about the benefits of scientific training than the nation as a whole.

Program Characteristics

The same groups of text programs analyzed earlier were also reviewed to determine the extent to which each of the desired program characteristics was present. The results are summarized in the following table:

EXHIBIT VI-B
Congruence of Existing Program Characteristics to Desired States

	Characteristics	Frequently Used Texts	NSF Texts	New Generation Texts
1.	Interdisciplinary	Low to None	High to Good	High
2.	Alternatives	None	High	High to Low
3.	First Hand Experience	Low	High to Good	Good
4.	Involved in Data-Gathering	Easily Avoided	High	High
5.	Alternative Modes	Single-Mode Text	Single-Mode Text Hands-On	Combination
6.	Reflects How Children Learn	Low	High	High

There is a marked contrast between the first group of texts and the other two. The influence of the NSF programs is very evident in the program characteristics of the third group.

Program Dissemination

Some evidence that information on new program ideas has not gotten to the appropriate decision makers is seen in the lack of change in the practice of science teaching in the elementary school. During the past 25 years, science teaching practice has been remarkably stable (Helgeson, et al, 1977, pp. 15, 93); thus, one might infer there has been little effective dissemination of new methods. The most common teaching technique is lecture-discussion (Helgeson, et al, 1977; p. 98; Weiss, 1978, p. B-60; Stake and Easley, 1978, p. 13:89). The time spent in science instruction today is virtually the same as three years ago (Weiss, 1978, p. B-6). Most teachers (61 to 92 percent) have never heard about new science curricula (Weiss, 1978, p. 38). Almost one-fourth of the schools use texts written prior to 1971 (Weiss, 1978, p. 95). Where new science curricula are being used is most likely in a school where the principal or teacher has participated in an NSF institute (Weiss, 1978, p. 81) and where teachers are hungry for change (Weiss, 1978, p. 100).

Specific dissemination strategies should emphasize information sources valued by teachers. The most valued information source for teachers is other teachers, followed by college courses (Weiss, 1978, pp. 73, B-11). Science resource staff are also used significantly (Helgeson, et al, 1977, p. 94), although only 22 percent of districts have science resource people (Weiss, 1978, p. 39). NSF institutes and related programs were helpful (Helgeson, et al, 1977, p. 13), but reached no more than five percent of teachers (Weiss, 1978, p. B-8). In addition to teachers, some resource staff and NSF institutes, principals are seen as significant potential sources of information although only nine percent of them feel they have an adequate background and 20 percent feel they are "not well qualified" to assist in science (Weiss, 1978, p. 46).

Program Adoption

Evidence of the extent to which the NSF curriculum projects are being used in the elementary schools varies depending on the report and level of analysis (school, teacher or classroom). The Weiss survey reports that 31 percent of the elementary school districts used one of the NSF programs (Weiss, 1978, p. 29). Another report indicates that in 1975, 17 percent of the elementary students were enrolled in schools using SCIS, 12 percent ESS, and 20 percent SAPA (Helgeson, et al, 1977, p. 18). This can be compared to the usage of the three projects reported by teachers (Weiss, 1978, p. 83). This report indicates that 20 percent of K through 3 teachers are using federal programs and 27 percent of 4 to 6 teachers. Larger districts with greater per-pupil expenditures are more likely to use the NSF materials (Weiss, 1978, p. B-32).

Teachers who do not feel confident in their knowledge of science are the major selectors (Weiss, 1978, p. 99) and determiners (Stake and Easley, 1978, p. 13:5) of the elementary science curriculum. Most teachers, 46 percent at K through 3 and 56 percent at 4 through 6, use a single textbook/program (Weiss, 1978, p. 89; Stake and Easley, 1978, p. 13:59). Pressure groups and public understanding of science affect textbook selection (Helgeson, et al, 1977, pp. 113, 116).

There are many factors that seem to affect the local educational climate and, therefore, the adoption of innovative programs. The desirability of inquiry is not a strong influence in the teaching of elementary science (Stake and Easley, 1978, pp. 12:8, 16:7, 12, 31), and many feel it requires too much work (Stake and Easley, 1978, pp. 12:4, 15:7).

The "back-to-basics" movement has had a significant effect on the schools in recent years (Stake and Easley, 1978, pp. 13:34-5), but the influence on science is not clear. Elementary principals believe that science is a basic but the three R's should be taught first (Stake and Easley, 1978, p. 18:55). The "socialization" responsibility of teachers is a major influence on what is taught and how (Stake and Easley, 1978, p. 16:7). Socialization goals lead to emphasis on (1) extrinsic motivation, (2) attention to directions, (3) homework and (4) testing (Stake and Easley, 1978, p. 16:21). Socialization is more powerful than scholarship (Stake and Easley, 1978, p. 16:23) and may explain why teachers react negatively to innovation (Stake and Easley, 1978, pp. 16:26, 17:27). It also may explain why many workshops and institutes have not met teachers' needs. The belief in socialization has led to a rejection of "inservice that transports teachers out of their environment into a different one with plenty of materials, shows them how to use them, and then sends them back home to recreate what they learned without any support. Unless workshop instructors come to the teacher's own classroom, work with her children, use her materials and show that children respond positively—there is little chance of success." (Stake and Easley, 1978, p. 16:23).

Program Implementation

Teachers mentioned many implementation "barriers" to explain the state of science teaching, such as:

1) Science is difficult to teach—requires more work and is less enjoyable.

   "A substantial number of teachers do not enjoy science themselves, do not take science-related coursework after they graduate, and do not study science on their own." (Helgeson, et al, 1977, p. 122). Further, some teachers found "NSF programs too demanding."

2) Lack of time

   Teachers feel there is a lack of time to prepare, collect, organize, set up, take down, clean up, and store—especially within the context of other pressures (Weiss, 1978, p. 15:7). Others feel they don't have time for hands-on science (Stake and Easley, 1978, p. 15:7).

3) Traditional text teaching

It is apparent from the studies that most science is taught through textbooks (Weiss, 1978, p. 13:5). "The source of knowledge authority. . . was not so much the teacher--but the textbook" (Stake and Easley, 1978, p. 13:59). Teachers are satisfied with programs/texts they now have (Weiss, 1978, p. 100). The use of materials other than the text is limited as indicated in this summary statement:

> "With or without regret, few teachers are engaging students in learning by experience. Most accept the equivalence of learning by experience and learning through instructional media (mostly the printed page) and see the student as getting greater volume via the media because of the efficiency involved" (Stake and Easley, 1978, p. 15:7).

4) Lack of dissemination of alternative science programs

Most teachers (61 to 92 percent) have never heard about new science curricula (Weiss, 1978, p. 38). About one-fourth of the schools use texts written prior to 1971 (Weiss, 1978, p. 95). Further, in 1974 only 14 percent of elementary teachers had attended an NSF institute.

5) Decline in supervisory leadership

Although teachers perceive supervisory assistance as valuable, the failure of most districts to employ science supervisors greatly limits the help available. Teachers are more comfortable when science consultants are available (Helgeson, et al, 1977, p. 191). This information is supported by the fact that 30 percent of K through 3 and 38 percent of 4 through 6 science teachers stated they did not receive adequate assistance. Sixty-one percent of K through 3 teachers and 52 percent of 4 through 6 teachers rated other teachers as being very useful as sources of information, while 27 percent and 21 percent of K through 3 and 4 through 6 teachers respectively rated specialists as very useful and 33 percent and 23 percent rated principals as very useful (Weiss, 1978, p. B-117). Other data indicate that only 22 percent of districts have a supervisor available with as much as 75 percent of the time devoted to science (Weiss, 1978, p. 39). It was found that fewer than 25 percent of those K through 6 science supervisors attend national meetings and only 12 percent belong to NSTA (Weiss, 1978, pp. 42-43).

6) Lack of budget and facilities

More than 40 percent of the K through 3 teachers listed lack of equipment, money to buy supplies, storage space, and paraprofessional help as areas where improvement is needed. The four through 6 teachers listed facilities (42 percent), equipment (55 percent), money for supplies (57 percent), storage (58 percent), preparation space (50 percent), and small group space (54 percent) (Weiss, 1978, p. 136). There is near universal agreement that school dollars for science are declining (Helgeson, et al, 1977, p. 142; Stake and Easley, 1978, p. B-2). While 40 percent of schools have required instruction in science (Weiss, 1978, p. 20), only 16 percent of the schools have a known budget for science (Weiss, 1978, p. 126). Despite the fact that funds are short, a poignant question asked is "whether more money would buy better education." (Stake and Easley, 1978, p. B-17).

7) Lack of paraprofessional help

Forty-eight percent of K through 3 teachers and 56 percent of 5 through 6 teachers reflected this concern (Weiss, 1978, p. 136).

8) Lack of prerequisite skills

The lack of training in science disciplines was perhaps the biggest obstacle to elementary programs (Stake and Easley, 1978, p. 2:22). Nearly two-thirds of elementary teachers feel "very well qualified" to teach reading. Twenty-two percent feel qualified to teach science, 39 percent social studies and 49 percent math (Weiss, 1978, p. 138). In another survey elementary teachers' perceptions of their qualifications to teach science were: not well qualified (16 percent), adequately qualified (60 percent), and very well qualified (22 percent) (Weiss, 1978, p. 142). Another source states most elementary teachers have not participated in "intensive institutes" (Helgeson, et al, 1977, p. 3).

"Although a few elementary teachers with strong interest and understanding of science were found, the number was insufficient to suggest even half of the nation's youngsters would have a single elementary year in which their teachers would give science a substantive share of the curriculum and do a good job doing it" (Stake and Easley, 1978, p. 19:3).

Ninety percent of the nine-year-olds reported that their teachers asked questions about science; seventy-three percent felt their teacher liked for them to ask questions and 66 percent felt encouraged to give their own ideas. In addition, 93 percent said it felt good to find something out on their own. However, in contrast to those feelings, 61 percent of the nine-year-olds said they would rather be told an answer than have to find the answer on their own, and 77 percent do not like questions to which they do not know the answer (RC01T03, RC04A08). Unfortunately, only 57 percent of the nine-year-olds wanted more science.

DISCREPANCIES AND RECOMMENDATIONS

There are three major areas of discrepancy between the desired state of elementary school science outlined in the first section and the actual state described in the last section. These are:

1) **The student outcomes consistent with the four goal clusters and the supporting program characteristics are not accepted or valued as a basic part of the education of an elementary child by parents, school administrators and most teachers.**

2) **There are many barriers or conditions that exist which prevent good programs from being implemented in many schools.** Some of these which have been repeatedly documented may not be real. They may simply be a statement that the teachers, administrators and parents are not willing to solve the problems involved because they do not value the outcomes of the program (see #1). Research is needed to determine which barriers are real and which are not.

3) **Teachers do not value and are not prepared in the content, methodology or goals of exemplary programs of science instruction.**

These three areas will be discussed in more detail, and a series of recommendations made to attack and reduce each discrepancy.

Getting the Community to Value the Teaching of Science

Today, as in yesterdays, we see the influence of parents making their desires known, school managers translating these desires into schooling goals and teachers further filtering these desires into the reality of their classrooms. In recent Gallop Polls it was found that more than half of the parents believe that schools should devote some attention to teaching basic skills and to enforcing student discipline. A recent newspaper headline (Chicago Tribune, March 7, 1979) reported that, while educational budgets in the country have skyrocketed from 36 billion in 1961 to 150 billion in 1979, decline in performance is attributed to the permissiveness in the classroom. Students are learning less because they are being taught less. Back-to-the-basics, which had the support of 83 percent of the parents, is defined by many to include respect, manner, politeness and discipline.

As school managers have listened thoughtfully to the concerns of parental groups, they have translated these concerns into two types of goals for schools--socialization and scholarship. Subject matter knowledge as an end in itself has rapidly been transformed into a vehicle for meeting the parents' demands for socialization (Stake and Easley, 1978, p. 15:5). The elementary science program described in the Desired State section of this report with its emphasis on the process of science and flexible content requirements, taught in an active (often messy) hands-on method is in direct conflict with the socialization goals. When socialization includes such outcomes as students responding to external rather than internal motivation, following directions, doing assigned tasks and conforming to authority expectations, it is viewed as the antithesis of an inquiry-oriented science program. When demands of parents show a shift to these basic goals, school management support for elementary science simply disappears (Stake and Easley, 1978, p. 17:8).

Teachers believe that teaching science as inquiry has been tried and that it did not work. From their perspective, too much emphasis on discovery-learning, hands-on-demonstrations, field study and contemporary topics have not helped the student (Stake and Easley, 1978, p. 15:4). Such instruction appears undisciplined, unproductive, and certainly not work-like (Stake and Easley, 1978, p. 12:8). Such instruction has not helped students get ready for later schooling (Stake and Easley, 1978, p. 15:4). As teachers have read the signals from parents, test scores and school management concerns, they have adopted more formal instruction as the best way to "contain and control the students" while preparing them for life. Students recognize that in this more formal instruction learning is not by doing, but by reading (Stake and Easley, 1978, p. 13:51).

The persistent pattern in the plethora of messages from parents, school managers and teachers is that science as an open-ended excitement and joy in understanding more about one's environment and in seeking and finding answers to questions is not a part of the expectation of schooling. Can science educators respond in intellectually honest ways to the school situation?

Recommendation 1: **Clarify both the goals and priorities of the various decision makers—parents, school administrators and teachers.** What are their criteria for accountability? "What do they want from school," is a question that needs careful documentation.

Recommendation 2: **Identify the programs and teaching methods, the outcomes of which are congruent with the goals of parents, school administrators and teachers.** Ways must be found in which science education goals become their goals, i.e., owned by them. This can be done by showing specific examples of ways in which existing materials enhance basic skill development, improve attitude toward schools, and nurture rational decision making. Empirical data are needed that will demonstrate the impact of science taught on student outcomes which are congruent with the values of parents, school administrators and teachers. In this way, science can be seen as part of the solution to the problems decision makers see as significant.

Reducing the Barriers to the Desired Elementary Science Program

In addition to lack of parental support, elementary science education suffers from a number of teacher-perceived barriers.

Most of the data on barriers are based on the self report of teachers and administrators. There appears to be little information from actual, systematic research on the conditions necessary to teach the desired programs. To what extent are the barriers listed in the Actual State section real? To what extent are they a result of the value structures of the parents and administrators and the training, interests and value structures of the teachers?

Are the lack of time and the fact that science is more difficult to teach real barriers or a reflection of the values of teachers and communities? Both certainly could reduce the extent or degree to which the desired program can be taught, but much can still be done in a reduced time allotment. The same holds true for budget and the lack of paraprofessional help.

The influence of traditional texts and the lack of dissemination of alternative science programs may also be artifacts of other problems. If teachers do not feel that alternative inquiry-based materials are important, information concerning them will fall on deaf ears.

We suspect that with the exception of a few dire circumstances, if teachers are well prepared and science is valued, the barriers will not prevail.

Recommendation 3: **Determine which barriers are real through carefully controlled classroom/teacher observations.** Although time and money are obviously necessary to teach science, how much of each is needed? There is considerable informal evidence that solutions to many of the barriers are necessary, but not sufficient to insure the teaching of science. Many of the barriers may be raised as smoke screens to mask the personal, teacher-related barriers.

Recommendation 4: **Conduct case studies in selected school systems where science is being taught effectively at the elementary level.** This should reveal what the enablers are. Because of random sampling techniques, the NSF-sponsored case studies emphasized the barriers to science instruction. Exemplary programs were not observed.

The gap between the desired states for school personnel and what actually exists is sizable. While it is desirable that school personnel feel confident (and if not enthusiastic, at least interested) in teaching science, there is every indication that elementary school teachers feel uncomfortable (in many cases, inadequate) with science as a subject and show little interest in teaching it. While it is a desirable state that teachers have an understanding of how young children learn and demonstrate appropriate teaching strategies (i.e., use of concrete materials, appropriate questioning, appropriate grouping strategies, etc.) there is every indication that a majority of teachers are unaware of the Piagetian literature; use few, if any, concrete materials in their teaching; and use lecture-discussion as the major teaching mode (Weiss, 1978, p. 106; Helgeson, et al, 1977, p. 32; Stake and Easley, 1978, pp. 16:7, 18:8-9, 19).

The data indicate that elementary teachers will increase their use of inquiry/process-oriented science lessons when exposed to the appropriate training (Helgeson, et al, 1977, p. 66). The problem is their inability to gain access to the training. There is also evidence that the NSF institutes have been effective, but these programs have been extremely limited. Science teachers who have attended one or more NSF-sponsored activities are considerably more likely than other teachers to use manipulative materials at least once a week (Weiss, 1978, pp. 118, 120). More time is devoted to science in classes using NSF-sponsored materials than in those not using such materials (Helgeson, et al, 1977, p. 32).

Because of the decreasing student population, fewer prospective teachers will be passing through the colleges in the future. Therefore, inservice education will be the only avenue of access for a great majority of teachers.

Recommendation 5: **Provide massive support to universities, states, consortia of school districts and individual districts to develop local inservice courses that support the desired quality of instruction.** These inservice programs should be associated with district level change processes, and combined with local efforts to improve elementary science instruction.

Getting Science Taught—A Systems Approach

The discrepancies listed above come from all levels of the system. The values and goals of the parents, citizens and teachers are involved. Many of the barriers represent a lack of support from the administration (and ultimately the community). And the teacher, of course, has the final say on the quality of the program in a given classroom of students.

Because all levels of the school system are involved, the entire system should be attacked in an organized fashion. There is evidence that the institute approach to the training of teachers and administrators is effective, but there is also evidence that sending teachers back to a classroom in a school where an inquiry-oriented teaching approach is not valued and supported negates effective training. If the priorities of the community and the system do not support the teaching of science, developing teacher skills will be of little benefit when they return to the local school. The barriers to effective instruction probably will not be removed as long as science is not a priority within the system.

When the problems in the first two levels (community and school administrators) are left unresolved, the enthusiastic and prepared teachers face almost unsurmountable difficulties in presenting a desirable science program. Yet, the solutions in the past (i.e., NSF-supported curriculum materials and teacher training institutes) have addressed only the last level (the teacher). Since good curricula are now largely available and teacher preparation and know-how are present, the solution in the future requires working on the rest of the system.

Most of the above recommendations can fit logically into a systems approach. The essential piece still missing is the resource person to create and carry out the plan.

Recommendation 6: **Provide significant funding for identifying and training resource and supervisory help at both state and local levels on a trial basis (three to five years) at a limited number of sites.** Document the effect these change agents have in bringing about the implementation of the desired programs. These science resource people should have a good knowledge of exemplary curriculum and of systematic implementation processes, and access to outside expertise as needed. If this trial is successful, long-range funding on a broad scale should be provided. A national training program for resource persons would be an important prerequisite to installing the processes extensively at the local level.

If elementary science teaching is to be improved, massive support of implementation activities is needed. The last twenty years of elementary science education has been largely devoted to curriculum development. The next twenty years should be spent on implementation.

VII. INTERACTION OF SCIENCE, TECHNOLOGY, AND SOCIETY IN SECONDARY SCHOOLS

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INTRODUCTION

The science-technology-society (STS) Focus Group of Project Synthesis was charged with the task of interpreting the states of science education from the perspective of those concerned primarily with the interface of science, technology and society. This perspective is in contrast to the perspectives of specific disciplines and of scientific inquiry. The STS perspective is not limited to considerations which grow out of work within those disciplines, but also incorporates concerns which originate from the society which is impacted by developments in science. The domain of STS does not have any one traditionally accepted definition as do the domains of physical and biological science. For that reason, the STS group spent considerable effort in the definition of the STS domain.

The definition of technology as perceived by this focus group must precede any discussion of the desired state of science programs in terms of their treatment of science-technology-society interactions. We accepted a rather broad definition of technology which includes both "Hard" and "Soft" technology. Hard technology encompasses the hardware developed for use by humans. This ranges from the first crude weapons and tools of primitive man to the most sophisticated computer. Soft technology includes the systems involved in the development and use of technological devices, as well as the systems involved in solving problems in industry and society at large, including behavior modification. Low level technology is described as the type of work which semi-skilled technicians do: wiring a lamp, changing a tire, or changing a washer in a faucet, etc.

The traffic control system in a community involves all three technologies: the lights, timing mechanisms, machines which stripe the roads, signs, roads are all hard technologies. The system which is designed to control the traffic (i.e., laws, timing sequences, maintenance schedules, procedures for the analysis and evaluation of the system) are all soft technologies. The changing of the burned-out light, installation of traffic lights, or striping of the road are all low level technologies. The impact of the entire traffic control system on individuals and society is an example of the science-technology-society interface.

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The following section of the report is a statement of the desired state for the teaching of science-technology-society issues at the present time. Since there are very few organized science-technology-society courses presently being taught at the secondary school level, it was necessary for the focus group to identify and describe specific areas of concern. These areas are:

- Energy
- Population
- Human Engineering
- Environmental Quality
- Utilization of Natural Resources
- National Defense and Space
- Sociology of Science
- Effects of Technological Development

The list of topics above represents areas which are commonly identified as fitting the perspective of this focus group. They are not the only topics that could be listed and we make no claims to have listed the eight "most significant" topics. However, these topics do exemplify the kinds of issues with which we were concerned and about which we sought interpretations. From our inspection of the data, we sincerely doubt that different, but similar lists of topics would have led to different interpretations or conclusions.

DESIRED STUDENT OUTCOMES

In the following pages, we present examples of learning objectives which further serve to define the intersect of the eight topic areas with the four Project Synthesis goal clusters, around which much of this study is organized. It is important to remember that objectives listed here are just a few of the many one might identify. They do represent, however, the kind of things we were looking for, not the specific details for which we searched. Once again, we are convinced that our interpretations and conclusions would not have been significantly altered if we had used different, but similar, lists of desired outcomes. Neither was our study greatly affected by the format in which the example objectives were presented. If they had been stated topically, behaviorally, or in terms of classroom activities, the conclusions would have been the same. The desired student outcomes are to some extent unique to the science-technology-society perspective; therefore, considerable space is devoted to their description by example.

Goal Cluster I - Personal Needs

Science education programs should prepare individuals to utilize science for improving their own lives and coping with an increasingly technological world.

Energy

Science education programs should provide the individual with an understanding of the energy problems from a personal perspective. This outcome should allow the individual to perform such representative tasks as to:

1. Describe/demonstrate specific ways by which an individual can decrease energy waste;
2. Evaluate the various tradeoffs associated with decisions involving his/her own energy conservation plan; and
3. Apply rational processes of thought to a proposed solution to his/her problems related to energy resources and their efficient use.

Population

Science education programs should provide individuals with an understanding of their role in population dynamics. This outcome should allow the individual to perform such representative tasks as to:

1. Discuss the implications of alternatives regarding family planning;
2. Using the skills associated with values clarification assess his/her own perceptions of current strategies which may or may not contribute to population problems (e.g., birth control, food production/ distribution, pharmaceutical advances, organ transplants); and
3. Describe the impact that technological advance has had on the family unit in different type communities and predict future impact (e.g., transportation, new and obsolete careers, improved health services).

Human Engineering

Science education programs should provide the individual with an understanding of the emerging problems in the field of human engineering. This outcome should allow the individual to perform such representative tasks as to:

1. Describe various methods of human engineering (e.g., abortions, organ transplants, cloning, genetic engineering, and behavioral modification);

2. Accept responsibility for decision making regarding the solutions and/or directions of family situations (e.g., life, living will, organ banks);

3. Apply rational thought processes to issues of human engineering which may confront the individual (e.g., life, behavior modifications);

4. Be aware of the value of genetic counseling as a mechanism for personal human engineering; and

5. Demonstrate some appreciation/understanding of the impact of human engineering upon traditional belief systems at the personal level (e.g., cloning, genetic engineering, behavioral modification).

Environmental Quality

Science education programs should provide the individual with an understanding of the various aspects of environmental quality and that those aspects may differ with other individuals. This outcome should allow the individual to perform such representative tasks as to:

1. Identify those elements in the environment which contribute to or distract from environmental quality;

2. Describe the significant role that the individual and his/her family play in contributing directly and indirectly to the environmental quality;

3. Employ skills and knowledge to improve his/her environmental quality, and;

4. Develop personal values towards an improved quality of his/her environment and demonstrate behavior through life that indicates a desire to improve it.

Utilization of Natural Resources

Science education programs should provide the individual with an understanding of the various aspects of utilizing the earth's natural resources. This outcome should allow the individual to perform such representative tasks as to:

1. Identify the common natural resources of the world and classify them as either renewable or non-renewable;

2. Describe how he/she is a consumer of the various natural resources and what effect the consumption of these resources has on the individual's standard of living;

3. Describe methods for decreasing his/her consumption of natural resources and/or what renewable or recyclable resources can be substituted for a nonrenewable resource without appreciably reducing his/her standard of living; and

4. Explain how a technique that could be used to decrease the consumption of a natural resource may have an undesirable effect on another natural resource (e.g., tuning a motor for better gasoline mileage may increase air pollution; returning a small quantity of material to a recycling plant may use more energy than it saves).

Space Research and National Defense

Science education programs should provide the individual with an understanding of the various accomplishments of space research and national defense programs. This outcome should allow the individual to perform such representative tasks as to:

1. Describe examples of various "spinoffs" of the space and national defense programs (e.g., heart pacemakers, biotelemetry, "space age" materials, transistors);

2. Describe how these various technological advances could affect the individual; and

3. Develop process and content skills necessary to evaluate the short and long term effects on the individual of proposed space and/or national defense projects.

Sociology of Science

Science education programs should provide the individual with an understanding of the sociology of science. This outcome should allow the individual to perform such representative tasks as to:

1. Work as a team member in science projects; and

2. Describe why scientists need to consider the sociological effects of their individual accomplishments.

Effects of Technological Developments

Science education programs should provide the individual with an understanding of the effects of both hard and soft technological developments on individuals and society in general. This outcome should allow the individual to perform such representative tasks as to:

1. Explain the strengths and limitations of the systems approach to solving personal problems;

2. Solve real and simulated personal problems by using a systems approach;

3. Identify technological developments that are appropriate solutions for a specific situation, and also, how some of them may often be dangerous (e.g., drugs, pesticides, reducing diets);

4. Judge the acceptability of consumer products in terms of proper use, safety, and cost effectiveness (e.g., smoke detectors, microwave ovens, fire-resistant fabrics); and

5. Examine and test various consumer products for safety of design and realize that some testing must be done by testing laboratories and not by individuals.

Goal Cluster II - Societal Needs

Science education programs of the community should prepare its citizens to utilize science to deal responsibly with science-related societal issues.

Energy

Science education programs should provide the individual with the background necessary for taking responsible action on energy related issues confronting the society. This outcome should allow the individual to perform such representative tasks as to:

1. Describe the relationship of a community's energy consumption to its quality of life, economics, and future development; and compare this relationship with those in developed and under-developed countries (e.g., developed countries use more energy and material resources per capita than under-developed countries);

2. Describe the role of interest groups and the various tradeoffs associated with the development of an energy plan; and

3. Evaluate the short and long range effects of proposed solutions to the energy problem.

Population

Science education programs should provide the individual with the background necessary to understand and react to problems associated with population dynamics. This outcome should allow the individual to perform such representative tasks as to:

1. Describe the impact that overpopulation and population distribution have on service elements of the society (i.e., energy, transportation, health care, supplies);

2. Describe how overpopulation will affect the environmental quality (pollution); and

3. Describe the long range consequences that population control will have on other structures of society (e.g., economic structure designed for expansion).

Human Engineering

Science education programs should provide the individual with the background necessary to develop insight into the emerging field of human engineering and its impact on society. This outcome should allow the individual to perform such representative tasks as to:

1. Describe the possible effects of emerging technologies to control life and death;

2. Explain the short- and long-range effects of continued technological control of humans (e.g., cloning decreases variability, mass media); and

3. Describe the ethical problems and threats to traditional belief systems caused by techniques of human engineering.

Environmental Quality

Science education programs should provide the individual with the background necessary to recognize the variations of the acceptable environmental quality of his/her community, state and nation, as well as to maintain or improve it. This outcome should allow the individual to perform such representative tasks as to:

1. Describe those characteristics of society that will substantially decrease the environmental quality (e.g., overpopulation, excessive industrialization, excess use of chemicals);

2. Be aware of the impact on this country's standard of living as the third world's consumption of natural resources changes (with a

finite quantity of non-renewable resources, any increase in use by the third world will reduce the amount available for use by this country);

3. Share with others his/her skills and knowledge of methods for improving the environmental quality; and

4. Develop attitudinal and community values which will be reflected in community practices and laws which will promote acceptable environmental quality (e.g., ban on open trash burning, car pooling).

Utilization of Natural Resources

Science education programs should provide the individual with the background necessary to recognize the societal problems involved in finding, using and conserving natural resources. This outcome should allow the individual to perform such representative tasks as to:

1. Describe the relationship between a society's consumption of natural resources and life style;

2. Give examples of how technology has increased and also decreased the rate of consumption of our natural resources;

3. Construct a scenario of the effect on the community of an increase in consumption of the Earth's natural resources by the third world countries; and

4. Explain why long-range planning for the management of natural resources is necessary.

Space Research and National Defense

Science education programs should provide the individual with the background necessary to react to the problems and potential benefits to society of the national defense and space programs. This outcome should allow the individual to perform such representative tasks as to:

1. Gain knowledge about research being done by military projects and space projects which present problems and/or benefits to society;

2. Describe how the benefit/cost ratio affects decisions on various space and military proposals and projects (e.g., communication satellites, nuclear aircraft carrier);

3. Explain why basic research projects do not have a benefit/cost ratio (e.g., deep space exploration); and

4. Give examples of long-range problems associated with storage and disposal of military and space projects (e.g., nuclear weapons, satellite re-entry, nuclear waste).

Sociology of Science

Science education programs should provide the individual with an understanding of the sociological effects of science and technology. This outcome should allow the individual to perform such representative tasks as to:

1. Give examples of the effects of several scientific and technological developments on society; and

2. Give examples of how societal pressures have affected the direction of scientific and technological research.

Effects of Technological Development

Science education programs should provide individuals with an understanding of the impact of technological developments on society, in order to make reasonable decisions regarding their responsibilities involving these effects. This outcome should allow the individual to perform such representative tasks as to:

1. Identify examples of technological developments that have affected society and state their strengths, weaknesses and potential payoffs (e.g., weather modification, automation, artificial organs, synthetics);

2. Cooperate in the use of technological devices and explain the reason for rules associated with them (e.g., traffic lights, pesticides, playing stereo too loudly);

3. Describe how technological developments have extended human capacity for the benefit of society; (e.g., communication systems, computers, force amplifiers, robotics);

4. Explain how research in one field often has payoffs in other fields (e.g., miniaturization in space programs and pacemakers); and

5. Examine and test technological consumer products for proper operation and/or safety or have sophisticated devices checked by testing laboratories.

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.

Background Knowledge

Science education programs should be included as an essential part of general education and provide the individual with the necessary process skills and knowledge of science and technology necessary to:

1. Conduct those representative tasks outlined in Goal Cluster I, 1-8 and Goal Cluster II, 1-8.

2. Pose and answer problems confronting the individual and/or society by applying scientific knowledge; and

3. Evaluate scientific knowledge, research and technology.

Shifting Knowledge

Science education programs should provide the individual with an understanding of the tentative nature of scientific knowledge so the individual will be able to:

1. Identify examples of scientific knowledge and/or technology that have become obsolete and how this has affected society;

2. Identify examples of breakthroughs in scientific knowledge and/or technology and how they have affected society, and

3. Describe how the potential and the limitations of science and technology are affected by research and societal values.

Continuing Education

Science education programs must provide a continuing opportunity for individuals to gain current knowledge in science and technology so the individual will be able to:

1. Inquire and increase one's scientific knowledge;

2. Apply scientific knowledge to new technology;

3. Evaluate the long-range impact of new scientific knowledge and technology on society; and

4. Prepare for new career opportunities as a result of the impact of new technology.

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.

Career Opportunities

Programs of science education should provide the individual an appreciation for career opportunities in science and technology. This outcome should allow the individual to perform such representative tasks as to:

1. Identify sources of information about career opportunities in science related fields (e.g., science teacher, engineer, other role models);
2. Describe why basic education in science, mathematics, and technology will enable an individual to move into many fields;
3. Give examples of career opportunities that have opened and examples of those that have closed as a result of the growth of science and technology;
4. Describe basic requirements of various careers in science and technology including not only the specific emphasis in a chosen field but also related preparation (e.g., engineers need English, biologists need chemistry, chemists need mathematics); and
5. Explain why scientists and engineers today need to have a broadly based education to better relate their chosen field to society (e.g., history, economics, sociology, shifting job market).

Career Decisions

Programs of science education should provide the individual the appropriate expertise/experience to make decisions and take advantage of career options in science and technology. This outcome should allow the individual to perform such representative tasks as to:

1. Compare his/her interests and capabilities with those needed in various science and technology careers as a result of having performed various roles in science-related activities;
2. Describe the value structure associated with various careers and contrast those with his/her own value structure (e.g., military research, disease control, medical research); and

3. Having chosen a career in science or technology, identify the academic preparation and related field experiences necessary to becoming employable in the chosen career.

Holistic View of Science

Programs of science education should provide a broad view of science and technology to insure that the perceptions of individuals are most complete. This outcome should allow the individual to perform such representative tasks as to:

1. Develop a picture of the structure of science and its relation to society to insure that the scientists of the future see the social context of science;

2. Acknowledge the ambiguities of science and somehow develop a mechanism to accommodate them to insure that the scientist of the future sees the potential pitfalls of science as operated in society (e.g., analytic vs. synthetic; objective vs. subjective);

3. Acknowledge the elements of science considered to be most troublesome by some, and relate them to the career of his/her choice (e.g., the uncertainty principle, optimization and self-correction); and

4. Give examples of how scientific and technological advances have been used and abused by society.

THE CURRENT STATUS OF STS TEACHING

With the above-stated goals and areas of concern in mind, the focus group examined the three studies funded by NSF and the one funded by the Office of Education (OE). The three NSF studies include an extensive review of science education-related research, a component of The Status of Pre-College Science, Mathematics and Social Science Education: 1955-1975 (Helgeson, et al, 1977), Case Studies in Science Education, which is an intensive study of what goes on in science classrooms (Stake and Easley, 1978), and the 1977 National Survey of Science, Mathematics and Social Studies Education (Weiss, 1978). The OE-funded project, the National Assessment of Educational Progress (NAEP), has completed its third and by far most comprehensive assessment of science knowledge, skills, attitudes, and educational experiences of pre-college students.

The following statements are a distillation of the findings of that examination.

1. Teachers rely primarily on textbooks for their course content. Evidence for this was found in all four data sources. Teachers, students and classroom observers all report an overwhelming reliance on science textbooks as THE curriculum.

2. There is little or nothing of STS in currently available textbooks. Our group reviewed a number of widely used textbooks (as reported in Weiss, 1978), and found virtually no references to technology in general, or to our eight specific areas of concern. In fact, we found fewer references to technology than in textbooks of twenty years ago. The books have become more theoretical, more abstract with fewer practical applications. They appear to have evolved in a context where science education is considered the domain of an "elite" group of students.

3. There are very few courses which attempt to meet the STS goals or areas of concern. Those which do are, because of the elitism among school people, known by such terms as "dumb dumb physics", etc. There are materials available for technology-related courses, but they are virtually unknown among science teachers.

4. Preparation of teachers to teach these courses effectively is essentially nonexistent in spite of the AAAS Guidelines of 1970 which urged such preparation. It appears that the science courses taken by most teachers in college are those designed to prepare specialists in science fields such as botany, physics, and geology. Such courses are generally quite theoretical and present much information within narrow disciplinary boundaries. Despite the fact that most high school students will not become specialists in scientific fields, the instruction they receive is patterned after college courses developed for specialists.

5. There is some attempt at inservice preparation of teachers and administrators, but this falls more in the awareness category than in the preparation category. Most inservice is apparently designed either to improve teaching methods or teachers' background in their discipline. Although both those goals are very important, they are unlikely to result in more emphasis on technology in the curriculum.

6. National Assessment found that there is a very low level of knowledge regarding these areas. For example, only 12 percent of seventeen-year-olds knew that most plastics come from petroleum, and only 3 percent were aware that the U.S. infant mortality rate is worse than that of most western European countries. Achievement on a number of National Assessment items in the STS domain was quite disappointing, and generally below achievement on more "traditional" items.

From the above findings, it seems safe to conclude that science education has accepted very little responsibility for education in the STS domain. Virtually every aspect of the science education enterprise has systematically avoided attention to topics such as those in the previous section of this report. Actually, as our society has become more technologically oriented, our science curriculum has become less so. Our group is deeply concerned by this state of affairs.

RECOMMENDATIONS FOLLOWING REVIEW OF DISCREPANCIES BETWEEN DESIRED AND ACTUAL STATE

Based on the discrepancies outlined above, the STS focus group made a series of recommendations to five specific groups:

School Personnel

Curriculum Developers

Educators of Teachers

Funding Agencies and Policy Makers

The General Public

It is understood that an individual and/or an organization may actually be in more than one of these groups. Further, a single recommendation may be appropriate for more than just one specific group. The recommendations which follow are therefore not organized by group, but are listed as tasks to be accomplished. The complete report includes more details on these recommendations including the groups to which they are addressed.

Although the following list of recommendations may seem rather long, many of the suggested actions are interrelated and can be carried out in concert with others. The length of the list also reflects our conviction that solutions simply will have little effect in bringing major changes to the system of science education. However, if there is a sincere desire to include the STS area in science education, actions such as the following should be effective.

1. School people (teachers, principals, curriculum committees and district level administrators) should encourage textbook publishers to include STS material in their texts in all areas of science.

2. School people should encourage the development and use of special publications, films, etc., presenting specific STS situations such as auto safety, fiber optics in communication, the connection between space exploration and the heart pacemaker. Connections and Search for Solutions are two such film programs.

3. Using knowledge gained from recent publications of new STS developments, individual teachers should be encouraged to develop their own curriculum materials to fit the teaching of the new development into their courses where appropriate.

4. A serious attempt should be made to introduce complete courses on STS into the school program for all students at the secondary level. These courses should not be limited to either the fast learners or the slow learners of the school but rather should be

directed to all citizens of a technologically oriented society as general education.

5. Whether or not textbooks include STS material, teachers should be encouraged to include the teaching of STS at appropriate places in the courses they are teaching. For example, an explanation of radioactive decay could include a discussion of the problems of disposal of radioactive wastes from nuclear reactors, or a lesson on how the eye sees might include a discussion and explanation of how the Optacon and Kurzweil machines aid the blind in reading directly from print or even from normal handwriting.

6. Science departments along with school administrators should be encouraged to discuss with any other interested groups the question of what should go out of the curriculum as more STS material comes in or, if it is possible, to include STS material so that it blends in with the standard course material so that little of the standard material needs to be eliminated.

7. Science departments along with school administrators should be encouraged to make more information regarding content of STS courses and potential careers in the STS area available to school counselors so that they might more effectively guide students into appropriate courses and careers.

8. School administrators should encourage and support teacher awareness conferences on STS curriculum and information regarding new technological developments. Recently the state school administrators in California and New Mexico supported such conferences for teachers and counselors regarding the potential careers in technology-oriented programs for minority students along with the curricular materials which would help those students achieve skills required for success in the field.

9. Many teachers are concerned that the inclusion of STS materials in their courses is not acceptable to state agencies and colleges. The state education department should make a special effort to assure teachers that the inclusion of such material is not only acceptable but is actually desirable at all levels.

10. School officials at all levels should facilitate the integration of STS materials in curricular areas other than science by encouraging personnel from the various areas to work together so that when appropriate, science, English, mathematics, and social science as well as business departments work together in the development of activities on a given topic. For example, the present TV system, which through minor technological changes can be expanded to become an interactive educational system, could have implications in science (the technology), business (the economics), social studies (the social implications), and English (the method of presentation) classes.

11. One of the problems which crops up regarding STS issues is that in some areas of the school, there is much "preaching" either for or against technology without the opportunity for students to make decisions which require a look at a number of alternative solutions to a specific problem. The energy crisis is one area in which social science and science teachers could work together to provide students with the opportunity to develop and examine all alternatives in the areas of education, legislation, and technology as potential solutions to the problem. They must then be encouraged to look at the secondary and even tertiary effects of each of the alternatives until they develop a real understanding of the statement: "For every complex problem there is usually an answer that is forthright, simple, direct--and wrong."

12. As clearinghouses are formed to include information and even curricular materials in the STS area, school teachers must be made aware of them through their administrators and be given encouragement and time to explore their contents for possible inclusion in their teaching.

13. State and local school systems should develop materials and systems for finding out what the students at various levels already know about technology as a basis for developing programs for carrying out the above recommendations.

14. Existing courses of study should be evaluated, and material which is obsolete and/or not relevant should be deleted. This will provide "space" to infuse into existing science programs selected topics dealing with the interaction of science, technology, and society (STS). Infusion of such topics into courses that are required (such as middle school science, general science, etc.) would insure that the total spectrum of the student population would be exposed to this important area.

15. A wide range of materials should be developed which would support both formal courses of study as well as community information programs. These would include such STS materials as: learning activity packets; movies; slide-tapes; compendia of articles from magazines (e.g., Solar Energy Digest, Popular Science, Mechanix Illustrated). Files of local field trips and community guest lecturers should be established.

16. Preservice and inservice teacher education programs must contain systematic strategies to develop teacher awareness of the importance of including STS in their science courses as legitimate subject matter for study.

17. Since curricula for Grades 7 through 12 appear to reflect the disciplines as modeled in the universities and since teachers tend to teach as they were taught, it is important that new courses on STS and technology education be developed at the college level.

Such courses would serve not only to educate students about appropriate issues and provide training in appropriate skills but would also serve as models for emulation to establish the credibility of STS in public education. These courses should be offered not only through the college or school of education, but also by the departments normally associated with arts, sciences, and engineering.

18. The general public should be given primary consideration as strategies are developed to include STS in the mainline textbooks. The general public should be included in the initial stages because, aside from being a partner in the educational decision making process, its influence among the larger audiences it represents is essential to insure that the STS inclusion in the mainline texts will be more than temporal.

19. In order to accomplish lasting change, it is further suggested that specific STS situations should be presented to the public via a series of special publications, television specials, radio spots, etc.

20. The experience of NSF course development in the 1960s leads to the conclusion that simply pouring massive resources into materials development would be ill-advised at this time. What is needed at the national level is continued modest development in materials accompanied by activities on other fronts which will serve to develop a sound foundation for broad-scale implementation sometime in the future. These activities can be classified into awareness activities, research activities, curriculum development activities, and leadership activities.

21. Because few people even know that technology education materials exist and because there is relatively little general knowledge regarding technological topics and issues themselves, we suggest large-scale national campaigns to increase the awareness of technology's impact on human lives. This campaign would be directed to teachers and their supervisory counterparts, to teacher educators, and to those involved in curriculum development, especially authors and publishers of widely used textbook series.

22. Biweekly newsletters entitled somthing like "Science, Technology and People" could be made widely available to teachers and others. They could include articles on the application of science principles (heavily valued by teachers) in technological developments and discussions of the positive and negative effects of these developments. Remembering from our data that teachers listen to other teachers more than to anyone else for curriculum advice, there could be articles written by teachers about technology-related class activities, field trips, etc., and individual or classroom activities could be included.

23. Because of the dominance of textbooks in science education, their selection becomes an extremely important decision at the local level. Criteria for textbook selection should be developed in such a way that they reflect science-technology-society concerns. Such criteria could be converted into checklists for use by states and localities in textbook selection. If such checklists had the credibility of endorsement by science teachers organizations (e.g., NSTA) and organizations of scientists (e.g., AAAS), there would be a better chance of their utilization in the decision process.

24. Because technology education is relatively new, the general understanding of factors relevant to technology education is not nearly as well-founded as the general understanding of more traditional areas of education. If efforts to promote technology education are to succeed, certain basic questions must first be answered by research activities. They include:

   o "What is the domain of technology education?" There are no generally accepted answers to this question. Our efforts to define the area in this project convinced us of the wide diversity in perceptions of the elements of technology education. Two related efforts could address this problem. First, there seems to be a need for a "taxonomy" of technology topics for education. A second need is for some systematically determined compendium of "important learnings" in technology education. Such a document would be different from a taxonomy in that it would be future oriented and would address the question: "Of possible knowledge relative to technology, which knowledge is likely to be most useful?"

   o National surveys of citizens' understanding of STS would provide important information for future curriculum development.

   o There also appears to be a need for research into the nature of the decision-making process which determines course offerings and course content. Our group was unable to get a very detailed picture of this process from the data base. We consider an understanding of that process to be a prerequisite to effecting changes in those decisions. It is important to know who those decision-makers are, i.e., what kinds of teachers are most involved, what roles do district and state supervisors play, what is the nature of lay influence, how do textbook sales representatives fit into the process, etc. Because technology-related courses at the secondary level are most likely to be elective rather than required, an understanding of the factors involved in student selection or rejection of such courses is also quite important.

- o There is also a need for greater "technology awareness" in the design of general research in the area of science education. The four major information sources used by Project Synthesis did not reflect significant attention being given to technology issues in the design or reporting of the research they reflected.

25. Materials developed for specialized courses in technology are also in short supply, and further development is needed in this area. Such development should be based on information gleaned from the research activities outlined earlier.

26. We strongly recommend that no major developments be planned or funded without substantial planning and funding for broad-scale dissemination of these materials.

Final Recommendation: Leadership Activities

There is an apparent need in technology education for a leadership and coordination function at the national level. The activities recommended earlier are likely to have little impact unless they fit logically into a coordinated group effort of those supporting technology education. We recommend the formation of a national center for leadership in technology/society education. Such a center would probably need to be supported for a number of years and would serve as a continuing stimulus for coordinated activity. It should serve as a clearinghouse for strategies, information, and ideas, and as a pro-active coordinator of research, development, and dissemination activities. One of the first activities of such a center should be a thorough study of resources available in technology/society education. Resources to be sought and organized would include funding sources; existing support groups, institutions, agencies, and individuals who support technology/society education; and materials and techniques which have been developed to aid technology/society education. Subsequent activities would then be designed to coordinate these resources into a viable national effort. We are convinced that such an effort is crucial at this point in our country's development.

VIII. PROJECT SYNTHESIS: SUMMARY AND IMPLICATIONS FOR TEACHERS

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Project Synthesis was a joint effort of 23 people representing a wide variety of roles and perspectives within the science education community. The purpose of the project was to make policy-relevant interpretations of a large body of data which portrayed the state of science education in the late 1970's. The task was approached with an objective and organized approach for digesting and interpreting a large and diverse information base. Many aspects of science education were assessed in light of important educational goals, student capabilities and limitations, and forces at work within educational systems. The process revealed a growing mismatch between the practice of science education and the needs of individual students and our democratic society. The basic problem is that the educational goals reflected by practice in science education appeared to be extremely narrow, and based on the erroneous assumption that most science students will go on to take considerable coursework leading to careers in science. Goals which appear to be largely ignored include preparation for citizen participation in science and technology-related societal issues, preparation to utilize science in everyday life, and preparation for making career choices in science-related fields.

This conclusion, if accepted by the education community, has massive implications for all activities related to science education. A major purpose of the Project Synthesis report was to share the evidence found in the data base, the ways that evidence was processed, and the lines of reasoning which have led to this conclusion. A second major purpose of that report was to suggest courses of action, especially those which policy makers can take to improve the situation. Those suggestions emerged from an analysis of the problems and of certain factors in school systems which tend to inhibit change. The purpose of this section of this monograph is to make interpretations and recommendations helpful to teachers.

PERSPECTIVES FOR STUDYING SCIENCE EDUCATION

Sections III through VII of this monograph include definitions of "desired states" for science education in terms of student outcomes and a number of elements of the education process. These "desired states" were developed to be consistent with broad goals (Goal Clusters) for science education. These "desired states" then became incorporated into perspectives for interpreting the data base. No attempt is made to summarize those desired states in this section of the report. However, some observations about the process seem appropriate:

- Once a determination of broad goals is made, it is possible to describe specific student outcomes and curricular characteristics consistent with those goals. This is a very difficult step, probably because we are not used to doing it.

- o Different goals do in fact translate into different kinds of course offerings, text materials, teacher requirements and classroom practices.

- o The translation of various goals into operational terms makes possible the evaluation of how well educational programs are meeting each of the various goals.

- o The intellectual process of carefully and thoughtfully translating broad goals into educational outcomes often has a significant effect on the way we view educational programs.

SYNTHESIS OF THE ACTUAL STATES OF SCIENCE EDUCATION

There was a large degree of consensus within and among the focus groups as to the general status of science education. Several generalizations emerged which reflect the conclusions of all focus groups, which are supported in various ways by all components of the data base and which appear to cut across curriculum materials, course offerings, enrollments, teacher characteristics, classroom practice and student outcomes. They are:

1. **At all levels, science education in general is given a relatively low priority when compared with the language arts, mathematics and social studies, and its status is declining. This low priority results in a general lack of support for science in most school systems.**

As reported by the Inquiry Group, "It was clear from the various data sources that not only the quantity, but also the nature of science education which occurs in the classroom is heavily dependent on the larger context in which education takes place. One important factor is the general esteem which the school and community hold for science generally. The evidence available in the studies reflects a positive view of science in schools and among those influencing schools. Nearly all teachers and counselors, school superintendents and parents recognize the need for minimal competency in science" (Stake and Easley, 1978, Chapter 18). However, there do not appear to be strong forces working to promote science education (Stake and Easley, 1978, p. 19:10). School superintendents do not appear to give science high priority (Stake and Easley, 1978, p. 17:20); state science requirements are declining (Helgeson, et al, 1977, p. 121), and there is some evidence that science education is being displaced by emphasis on areas such as the back-to-basics movement and vocational education (Stake and Easley, 1978, pp. 5:28, 17:19, 18:55). The lack of support often results in budget limitations which negatively affect the practice of science education. "In many locations, real money available for non-salary expenditures is dropping and the 'share of the pie' available for science has been declining as more budget pressure is being exerted by other needs, such as career education and special education" (Helgeson, et al, 1977, p. 122; Stake and Easley, pp. 19:25-26, 18:41, 6:23). About half the superintendents and science supervisors felt budget cuts had seriously affected the science curricula (Stake and Easley, 1978, p. 18:41).

2. Textbooks play a dominant role in science instruction.

The focus groups were generally convinced by the data sources that textbooks exert an overwhelming dominance over the science learning experience. Evidence to support this conclusion was apparent in all the data sources. The Case Studies found teachers to rely on texts (Stake and Easley, 1978, p. 19:6), reported data that 90 to 95 percent of 12,000 teachers surveyed indicated they used texts 90 percent of the time (Stake and Easley, 1978, p. 13:66), and summarized a number of points by saying, "Behind every teacher-learner transaction. . . lay an instructional product waiting to play a dual role as medium and message. They commanded teachers' and learners' attention. In a way, they largely dictated the curriculum. Curriculum did not venture beyond the boundaries set by the instructional materials," (Stake and Easley, 1978, p. 13:66).

Because of the dominant position textbooks hold in determining learning experiences, an analysis of "widely used texts" became an important step in determining the status of science education. The Biology, Physical Science, Elementary and Science-Technology-Society focus groups each reviewed a number of the textbooks found by the Weiss survey to be used most widely (Weiss, 1978, B44-B45). Generally, they were inspected to determine if they reflected the desirable program characteristics identified in Phase I.

3. Of the four goal clusters discussed earlier, only the goals related to development of basic knowledge for academic preparation receive significant emphasis. Goals related to personal use of science in everyday life, to scientific literacy for societal decision-making, and to career planning and decision-making are largely ignored.

The nature of the most widely used texts provides strong evidence for this conclusion. Generally, the most widely used texts in all disciplines at all levels were largely devoid of the characteristics representative of goals related to personal utility, societal issues and career choice, as defined by the four focus groups who analyzed texts. Although there was some rhetoric on the importance of such goals in the preface of some of the textbooks, there was notably little treatment of topics such as those identified by the focus groups as being representative of those three major goal areas. There was virtually no treatment of the relationship between traditional science concepts and the personal, societal or career choice decisions facing students, nor was there any substantive treatment of technological developments.

To illustrate the nature of the curriculum as exemplified by most widely used textbooks, an example of the kinds of things we were looking for and the kinds of things we found may be helpful. Consider, for example, the topic of insects. The typical high school biology course available to the majority of students includes a unit on insects. Some examples of possible learnings about insects which were looked for because they seem particularly useful in peoples' everyday lives include: the value of insects in yards and gardens (e.g., bees pollinating fruit trees, various insects eating other harmful insects); the damage done by insects in homes and gardens; ways of detecting this damage; and ways of controlling the harmful insects without endangering useful insects, our pets or ourselves. Learnings which reflect the goal of societal relevance include: the economic impact of insects on food supplies; the health threat posed by ticks, malaria-carrying mosquitos and other insects; the apparent necessity for the use of insecticides in intensive agriculture, the harmful environmental side effects of insecticides, and the consideration of tradeoffs between these two factors in making decisions about banning or endorsing the use of insecticides. Also important in understanding the interface between science, society and technology is knowledge of the development of new technologies (such as releasing sterile males) which control insects, etc. Career awareness activities related to the topic could reflect a wide variety of jobs from insect exterminators to entymologists who specialize in forest management. However, when the most widely used biology textbooks are reviewed, topics such as these are mostly ignored. What is found is a chapter which places insects taxonomically as arthropods. It goes on to devote the major part of the chapter to naming kinds of insects and describing in great detail the body parts of insects, especially the grasshopper. The scientific names of many parts of insects are presented. A short section on the behavior of social insects rounds out the chapter. There is virtually no attempt to associate insects with the experience of the students, to prepare students to deal with insects in their daily lives, or to understand the important societal issues involving insects, their control, and the side effects of such control.

This example was as representative of most of the junior high texts we reviewed as it was of the senior high texts, in the physical and earth sciences as well as in biology. It was a common experience in reviewing these texts to note places in the textbooks where it would be logical and easy to integrate information or activities relevant to the personal, societal or career-choice goals, but this was virtually never done. Such an integration could, for example, take the form of real world examples and references relating basic concepts to societal issues. Often, one sentence or a short paragraph strategically inserted would achieve much in this direction. The failure to make such insertions was considered as evidence that the ignored goals were given virtually no priority by those who prepared these popular textbooks.

Some textbooks do present fundamental knowledge in a more useful form. This was generally a characteristic of the materials developed with NSF funds. For example, the BSCS "Green" textbook discusses insects in terms of their environment and ecological functions. However, it still ignores the kinds of topics exemplified in the "insect" discussion above. Widely used physical science texts developed by national program developers for use at the junior high level have made great strides in attention to concept development and inquiry skills, but they place no more stress on personal, societal and career-choice goals than do other commercially available texts. For example, two widely used texts in this category, Introductory Physical Science and Probing the Natural World/2, are dedicated almost exclusively to development of concepts of force, motion, energy, a particle model of matter, and chemical reactions, all of which appear primarily of academic interest when not applied to common problems and phenomenon.

It is important to note here that we are speaking of widely used texts, as determined by the Weiss survey. It is possible that a thorough review of all materials available would identify textbooks with much broader goals. The Elementary Group surveyed three categories of textbooks. The first category, "widely used texts", fits the general description stated above. A second category of "NSF funded curriculum" and a third category of "new generation" texts are also identified and discussed in their report. These other two categories of textbooks, although not widely used, were considered by the Elementary Group to meet their criteria considerably better than those widely used in 1976. The Biology group also identified a number of texts written for general use at the college level which provided much better treatment in the personal and societal areas and some of which appear to be no more difficult than commonly used high school textbooks. The Science-Technology-Society group also identified materials dealing with technology concepts, but found that they were virtually unknown to science teachers.

Although space here does not allow a treatment of laboratory practices, testing, course enrollments, and other characteristics of science education, there was clear evidence in all the areas that the academic preparation goal dominated all aspects of practice. For evidence leading to this conclusion, the reader is referred to previous sections of this report and to the full body of the Project Synthesis report (Harms and Kahl, et al, 1980).

4. Teachers make most of the important decisions about course content, text selection and instructional methods, and in so doing they determine the goals pursued by science education.

Teachers appear to be the primary decision makers in the selection and use of curricular materials (Weiss, 1978, p. 99); teachers' involvement in this process, either as individuals or as part of selected committees, is far heavier than that of district supervisors, principals, or superintendents. School boards, parents and students are virtually never heavily involved in selection of materials (Weiss, 1978, pp. B48-B55). According to the Inquiry Group, "Not only do teachers make the ultimate decisions about the nature of the science they teach, they rely heavily on other teachers as sources of information about new developments. When asked what sources of information about new developments were most useful, teachers at the primary, elementary and junior high levels ranked other teachers above all other sources listed. At the senior high level, however, journals and college courses were ranked above teachers as sources of information" (Weiss, 1978, p. 152). This does not mean that all teachers have the opportunity to make unilateral decisions about the materials they use, as such decisions are often made by representative committees at the school or district level. However, there was considerable evidence that most teachers have autonomy in the way they utilize those materials to teach science (Stake and Easley, 1978, p. 13:3). "Almost every science teacher had strong ideas as to how the "basics" in science would be defined. . . and these ideas were continuing to be the prime determinant of what went on in the teacher's classroom" (Stake and Easley, 1978, p. 12:5). This autonomy apparently encompasses teaching style, modes of presentation, selection of tests, assignment of grades, and within the limits set by the administration, the determination of such things as out-of-school field trips and work experiences.

One striking observation is that the factors which affect teacher decisions about day to day practice do not appear closely related to the issues discussed so far in this volume. That is, the ultimate utility (or lack thereof) of science knowledge and skills did not appear to be central guides in determining teaching practices. Rather, a number of important factors determining practice were seen by the

Case Study observers as fitting within the general class of "socialization" (Stake and Easley, 1978, pp. 16:3-26). Socialization goals include inculcating students with the work ethic, teaching students to learn from a textbook, paying attention to directions or presentations, carrying out assignments, preparation for tests, preparing for next year, observing the mores of the community, respecting authority, competing, cooperating.

Turning our attention from the socialization goal to goals representative of the four goal clusters and inquiry teaching, it is possible to come to the firm conclusion that most teachers have a narrow perception of their responsibilities within these goals. The apparent primary goal of most science teachers appears to be that of teaching "fundamental knowledge" which is necessary to prepare students for later coursework. Goals related to preparation for using science in the personal, societal, and career-choice arenas, and goals related to inquiry appear to receive very little attention from teachers. The strongest evidence for this conclusion is the almost total reliance on textbooks, the nature of the textbooks themselves, and the fact that teachers choose these textbooks from the wide variety available.

IMPLICATIONS FOR SCIENCE TEACHING: NEW CHALLENGES

Information about the current status of science education has important implications for change at the district, school and classroom levels. Major shifts in educational needs require shifts in educational goals for many students. These shifts in goals can be achieved only if translated into new educational programs. Such program changes will probably require new objectives, new course offerings, new or revised materials, and a redefinition of teacher responsiblity. The purpose of this section is to discuss some new challenges to science education and some ways of meeting those challenges.

Changing Times Bring New Challenges

When we compare the world of the eighties with the world of the sixties, we see immense changes which impinge upon science teaching. Twenty years ago, the achievement of technological supremacy was seen by many as the most important national goal. The Russian launching of Sputnik, coupled with the belief that "the good life" depended on technological progress, provided a powerful stimulus for producing a large corps of engineers and scientists. Because technically trained people were in short supply, huge federal expenditures were directed towards meeting science manpower needs. Part of these expenditures went to revise curriculum materials and to train science teachers. One major purpose of that revision and training was to produce high school graduates who were better prepared to become scientists and engineers. The influence of that federal effort is evidenced by the approximately 4,000,000 students in United States schools now using NSF-developed materials, and by the evolution of privately developed materials that resemble the NSF materials in many ways.

Twenty years later, the world is much changed. The supply of scientists and engineers is now sufficient in most areas, and where there are deficiencies, they are generally caused by a limited capacity of colleges and universities to handle all the entering students who seek careers in science and technology. As a society, we have become wary of the unbridled growth made possible by new technologies. As a society, we are becoming aware of limitations of our natural resources. Shortages of energy, water, minerals, land and space on the one hand and environmental problems on the other, require us to view technological developments in new ways. The result is that the general public is taking considerably more interest in scientific and technological developments, and is actively participating in societal decisions on many science and technology related issues. This situation requires citizens in general to understand the scientific aspects of important societal issues.

Not only is there an increased need to understand large national issues, there is also an increasing need to understand the way science and technology affect us as individuals. **Thus, a new challenge for science education emerges. The question is this: "Can we shift our goals, programs and practices from the current overwhelming emphasis on academic preparation for science careers for a few students to an emphasis on preparing all students to grapple successfully with science and technology in their own, everyday lives, as well as to participate knowledgeably in the important science-related decisions our country will have to make in the future?"**

New Challenges Precipitate New Goals

One overarching responsibility faces every person associated with science education, from the local to the national level. The responsibility is to **rethink the goals** of science education in light of basic educational philosophy and the unique role science plays in all of our lives, and to redirect the science education system toward those redefined goals. We are confident that other persons who make an in-depth study of the status of science education will find pre-college science education almost completely dedicated to the academic preparation goal, and that they will agree that major changes are critically needed. We are also convinced that other thoughtful persons will come to conclusions similar to ours; that the goals of preparing the majority of students to use science in their everyday lives, to participate intelligently in group decisions regarding critical science-related societal issues and to make informed decisions about potential careers in science and technology are equally as important as the goal of preparing a minority of students for more advanced coursework in science.

New Goals Require New Programs

Because curriculum decisions are made primarily at the local level, the major responsibility for change lies at the local level, especially with science teachers. Because the changes recommended here may be antithetical to apparent basic assumptions and goal perceptions of many science teachers and because few new teachers are entering the system, a first requirement of any successful plan is the development of activities which result in the rethinking of goals and priorities. If these priorities shift toward personal and societal goals, we would expect changes such as those discussed below to occur. (Much more detailed descriptions of "ideal" programs can be found in the individual focus group reports.)

At the elementary level, teachers, principals and parents would consider science a "basic". Local support systems would provide the training, materials and organization necessary to enable the schools to provide good programs with as little special effort as possible. Currently available elementary curriculum programs would be implemented to produce the desired states described earlier in this report and in the elementary report.

At the middle school and junior high school level, the assumption that the primary goal of science education is to prepare for future coursework in academic science would shift to an assumption that the primary responsibility at this level is for general education. Materials used would address issues and topics related to personal, societal and career choice needs. Laboratory emphasis would shift, at least in part, from the "rediscovery" of scientific principles to investigations into the implications of scientific principles and technological developments for problems faced by individuals and by society. Decision-making and problem-solving skills would receive increased emphasis. Important science facts, principles and inquiry processes would still be essential elements of the curriculum. However, the context in which they are presented would be changed, and the criteria for selection of topics would be re-examined. Those principles, facts and processes which could be defended only because of their utility in advanced courses or in specialized fields would be de-emphasized. Some topics would disappear from the curriculum altogether.

At the high school level the picture would be more varied. The high school introductory biology course (offered at grade 9 or 10) would still capture very large enrollments. Because nearly everyone takes biology, a shift to general education emphasis with topics presented in a personal and societal context would occur. The effect of human activities (including bio-engineering) on the living world, as well as our dependence on that world and our responsibility for preserving it, would be emphasized. Much more emphasis would be placed on the human species than is currently the case.

Beyond grade ten, academic college-prep courses in chemistry, physics, and advanced biology would still be offered. However, to facilitate the preparation of responsible scientists and engineers, those courses would point out the relationship of developments in science and technology to life and problems of the late twentieth century. In addition to these revised existing courses, new courses would be offered to help students cope individually with an increasingly technological world and to participate intelligently in decisions requiring knowledge of science and technology. Such courses would attract some students who now are enrolled in the academic courses as well as many students who now take no science after biology. Although less quantitative than existing courses, they would not be "watered down" science courses but rather science and technology courses with a new emphasis. The physical sciences would no longer be considered the domain of only "academic" students; rather, courses stressing the many applications of physical and earth sciences to everyday life would be made available to all students.

The focus groups described a number of characteristics of curricula one would expect to find in educational programs which address the four major goal categories previously described and exemplified. First and most obvious, topics such as those appearing as "desired states" in Parts III through VII would be included in course materials. Second, it was the consensus of all five groups that any viable science program regardless of its goal emphasis would firmly rest on a foundation of basic aspects of science—i.e., skills, facts, principles and concepts. There is, however, a rather large universe of such aspects of science, and many ways in which they can be selected and built into curricula. Each of the focus group reports suggested specific ways in which topics could be selected and interpreted into curricular programs. A summary of points common to all focus group reports is included here.

One common element of personal and societal goals is the importance of the applications of science to problems of personal and societal relevance. In order for students to be able to apply science to such problems, it is necessary to have an understanding of the problems, of the aspects of science which apply to the problems, and of the relationship between science and relevant problems. Students would also have experience in the processes of applying science to the solutions of such problems. Science education programs designed to produce student outcomes such as these could logically be designed in at least two general formats. First they could present science in the context of personal needs and societal issues as suggested by the Biology Group. This is in contrast to science courses organized to display the structure and logic of a particular science discipline. Another approach would be to continue using the structure of the discipline as the course organizer, but to develop the content through applications to real world personal and societal problems likely to be encountered by the students. The Physical Science group suggested this second format as being appropriate for a major fraction of the physical science curriculum. In either case, considerable emphasis would be placed on presentations which would show the utility of science knowledge in situations likely to be faced by many of the students in later life, and which would provide the students opportunities to participate actively in such applications. Such active participation would include the identification and definition of problems to be attacked or decisions to be made; applications of the processes of scientific inquiry in acquiring, interpreting and utilizing information needed; and practicing skills of decision making in problem resolution. A variety of problems relevant to personal and societal issues would be included and a variety of processes for problem resolution and decision making would be employed. The science-related issues, the science concepts and principles, the processes of scientific inquiry, and the systematic decision-making models would be dealt with in an integrated fashion stressing the interrelationships among them.

Another common element of programs in all areas would be the inclusion of fundamental aspects of science. Obviously, basic learnings are important for students planning science coursework leading to careers in science and engineering. It was also the conviction of our groups that basic science knowledge is also essential for full understanding of science-related personal and societal issues. Decision-making or values-clarification learning activities which ignore scientific principles, research data or potential technological developments are pointless exercises leading to a pseudo-sophistication in science-related issues which is probably more dangerous for a society than is acknowledged ignorance.

One common criterion of educational programs designed to meet the personal, societal or academic goals is emphasis on the full spectrum of cognitive levels. Personal and societal problem solving and decision making require the application of science principles, concepts and processes to specific situations. Such applications require the acquisition and utilization of factual material, the interpretation of data, the analysis of complex problems, and the evaluation of alternative solutions and resolutions. Likewise, future coursework leading to academic careers in science will rely heavily on utilizing principles and concepts in new situations involving a number of variables. Thus, the simple acquisition of discrete facts and isolated principles is not in itself adequate for the pursuit of any of the important goals of science education.

Because virtually every topic in science is related to specific career options in science and technology, materials designed to achieve the career-preparation goal would have career information included as an integral part of basic textual materials. A chapter on genetics, for example, would discuss careers in genetic counseling, animal breeding, agronomy and basic DNA research. In addition, one would expect to find opportunities for individuals to explore careers of interest by talking with people in such careers, by doing research in school libraries, by on-the-job experiences as part-time workers or volunteers, by doing simulations. In general, science topics would be dealt with in such a way that the relationships between knowledge, the ways in which it was developed and the ways in which it is applied are placed in the context of the human endeavor and the roles played by various individuals and groups in acquiring and applying knowledge.

New Challenges Require Renewed Teachers and Classrooms

Ultimately, the degree to which any educational program achieves its goals depends upon classroom teachers. In all teaching disciplines teachers are needed who are dedicated to helping young people, knowledgeable in their teaching field, and skilled in the techniques of teaching. Additionally, certain teacher characteristics specific to science and to the four broad goals appear prerequisite to the achievement of those goals. Some of those teacher characteristics identified by the focus groups are identified in this section.

First, it is important that teachers base their curricular and instructional decisions on internalized rationale rooted in sound philosophies regarding science and education. A teacher with such a rationale has addressed questions about the broader goals of science education, has reached some resolution regarding the purposes science education should serve in society, and actively seeks materials, practices and techniques to achieve those purposes.

For science education of any sort to prosper at the elementary level, teachers must value science outcomes and consider them worth pursuing. An understanding of the contributions science can make to general cognitive development is one possible aspect of such a value system. Another important attribute for teachers at the elementary level is the perception that the study of science is much more than an exercise in reading comprehension. Rather, it is a vehicle for learning about the natural world. Teachers who view science in this way will naturally use a variety of techniques including direct observation, experimentation, individual and group projects, questioning, and reading. They will do this not only to help students learn about the natural world, but also to develop those processes of inquiry they can continue to use to gather and process information. Although the elementary group considered it unrealistic to expect teachers to have command of a large body of knowledge in science, they were convinced that confidence in the teaching of science was a necessary teacher characteristic. For confidence to exist in the absence of a broad command of scientific knowledge, it is necessary for elementary teachers to see science as a way of investigating simple and common phenomena, especially those in the immediate environment. Conversely, it is important that elementary teachers not feel it is their responsibility to convey a large body of facts, theories or "scientific" terms to their students.

Several teacher characteristics were identified by the focus groups as being logically associated with personal needs goals. Probably the most important teacher characteristic in this respect is the treatment of students as individuals and the consideration of their individual needs in determining what and how to teach. If this consideration is combined with a thorough knowledge of the applications of science in people's everyday lives, and with a perception of science as a way of knowing as well as a body of knowledge, one would expect to see certain practices emerge. Whether or not the curriculum materials include the topics and other characteristics identified earlier as being consistent with this goal, a classroom teacher would actively introduce such learnings into the curriculum. The teacher would also seek out ways in which the basic aspects of science and technology are applicable in the everyday lives of the locale in which the students live and develop learning activities to help students see those connections. Individual projects would be encouraged and problems of interest to individual students would be investigated.

A number of teacher characteristics and practices which one would logically expect to find in classes pursuing societal goals were identified by the focus groups. One important teacher characteristic associated with this goal is a thorough understanding of the interrelationships among scientific endeavor, scientific knowledge, technology, and many important societal issues and problems. This understanding, coupled with a conviction that it is important for future citizens to be as well prepared as possible to make group decisions in the arena of science-related societal issues, would logically result in certain patterns of practice within science classrooms. In biology classes, for example, one would expect at least some learning activities centered around biosocial issues (such as the ethical implications of human genetic engineering). Biological principles (such as the structure of DNA) would be presented in the context of the biosocial problems. Classes would utilize group inquiry efforts in seeking out knowledge pertinent to the issues and would employ systematic decision-making models in seeking resolution of the issues. In all classes, the teacher would serve as a role model in delineating issues, examining values, and in freely admitting error. Student questions, debates and philosophic discussions would be encouraged. Students would also be encouraged to seek out scientific knowledge from many sources including direct investigation, texts, reference books, scientific journals and the popular press. An important part of the learning process would be judging the appropriateness of various kinds of information for specific purposes and in discriminating among fact, opinion and wishful thinking. In effect, this entire process could be quite similar to the processes by which society in general would resolve issues ideally.

Teacher characteristics associated with academic preparation overlap considerably with those desirable for the other three major goal areas. Because a major component of the academic preparation goal is to help students develop fundamental knowledge, it is important that the teachers have understanding which enables a determination of what is fundamental. A thorough grasp of the ways in which practitioners in science and technology apply various aspects of science is helpful in determining which knowledge may be most useful later. It is also important that science teachers have a conceptual framework which ties together knowledge from various areas within their discipline, and among the science disciplines. In this way, they can select and elaborate on those more powerful unifying themes of science. Finally, an understanding of the skills and concepts needed (and not needed) in later coursework is important. Classroom practices logically related to the academic preparation goal would include use of a variety of media for the presentation of concepts, laboratory experiences which reflect the many ways in which scientists carry out investigations and discussions of the special responsibilities scientists and technologists bear in a free society.

The primary teacher characteristics associated with the career-choice goal are awareness of the importance of educational and career planning for students' futures and a sense of responsibility for input into career-related decisions. A teacher with these attitudes will naturally keep abreast of the science-related job market, be aware of sources of career information and community resources, and pass this information on to students as a natural and normal part of science classes. The aware teacher will find many opportunities to discuss specific careers associated with specific topics in science and science-related societal issues. In addition, the identification of local practitioners of science and technology who can speak directly with interested students would be extremely useful in this respect.

Regardless of a teacher's philosophic rationale or the degree of emphasis placed on general goals, it is unrealistic to expect that science teachers can pass on to students all or even most of the science information they will need in the future. Thus, it is extremely important that students be provided with a foundation of skills and attitudes which will prepare them for acquiring and processing knowledge in their future lives. One important attitude is the valuing of empiricism as an important and necessary information-getting mechanism. A teacher who can answer a student's question by saying "I don't know, but let's see if we can find out," can serve as a role model in inquiry. In order to succeed in this role, the teacher needs experience in conducting investigations, knowledge of various inquiry skills and awareness of many sources of information. In addition to serving as a role model in collecting information, the teacher should also encourage logical and reflective thinking in the utilization of the information gathered. This requires ability and experience in interpreting, analyzing, and evaluating information and in decision making for utilization of the information.

Teacher Renewal and Program Changes Require Professional Action Plans

The development of new educational programs and classroom practices suggested in the preceding two sections can occur only if teachers work systematically to achieve specific new goals.

The professional preparation of most science teachers, their classroom teaching experience and the textual materials they use assume much narrower goals for science education than those suggested here. Breaking out of such well established patterns is a difficult task at best and for most teachers will require some new skills, perspectives and courses of action. The purpose of this section is to suggest some professional self improvement steps teachers can take to move in that direction. The first four steps suggested here closely parallel early steps taken by each Project Synthesis focus group. These steps had considerable influence on those of us involved in them, and we recommend them as a possible starting point for others looking closely at science education. They are:

1) Determine broad goals for science education. Considering the ideas in this document and in other professional reading, make a list of the major educational goals that are thought to be important in classrooms and in particular schools. The goals should be written in terms of things students are preparing to do. The list should be kept short and manageable at this stage.

2) Identify student outcomes which are important to achieve each of these broad goals. The idea here is to come up with examples of things students need to learn if important educational goals are to be met. The desired student outcomes from the group reports in this volume may serve as a starting place, but it is also important to gain experience in translating broad goals to specific learner outcomes. This development of rationales connecting broad philosophically based goals and specific learner outcomes is an extremely important but usually neglected step in the development of student objectives and curriculum. We are not suggesting the development of long exhaustive lists of behavioral objectives. Rather what is needed is a definition by example of the kinds of student outcomes inplicit in the broader goal statements.

3) Identify course offerings, textbook characteristics, classroom practices and testing procedures which will produce and evaluate important student outcomes. Once again, reports in this volume or in the original Synthesis report may be a helpful starting point, but it is important to develop some specific ideas of what an ideal curriculum would look like in a specific school to achieve the educational goals a given teacher has determined to be important. It is also important to utilize tests developed with the new educational goals in mind.

4) Compare the "ideal curriculum" with the current curriculum. Take a look at specific course offerings. Are they consistent with the broad goals? How about the currently used textbooks? How

much stress do they place on each of the goals that have been identified? How much class time is spent, for example, in dealing with societal issues or the effects of technology, career possibilities or applications of science to everyday problems? Making a brief list of the most important discrepancies found between the actual and the ideal program may be useful.

5) Decide on a course of action. There are a number of ways in which educational programs and practices can be made more consistent with broad educational goals. They include:

- Developing new teacher competencies to deal with changing needs. Most individual teachers' preparation probably did not include many courses which made important connections between the science disciplines and personal and societal applications of science. Likewise, there was probably little coursework dealing with new technologies or the many new career options opened by scientific and technological developments. Many emerging science-related societal issues are not usually covered in teacher education. These issues abound in the fields of energy, environment, natural resources, population growth, genetic engineering, etc. As one continues to complete college or university coursework, it is probably possible to find formal courses at the college level in a number of these areas. Such courses are becoming much more common in colleges of arts and sciences as well as in engineering schools.

  Another important path to professional improvement is through teacher inservice. To the extent that teachers influence local inservice programs, they can encourage the development of programs which stress the areas suggested above. There is little precedent for such programs, and some innovative ideas are probably needed to make them work. For example, the use of non-college-based lecturers (e.g., from engineering, environmental groups, energy companies, employment agencies, etc.) can add an important "real world" flavor to traditional academic instruction.

  Finally, an important part of keeping up-to-date in any profession is the reading of journals and magazines as well as watching special T.V. programs and other media sources which cover new developments. As one perceives the role of science education to broaden into the personal and societal areas, it is possible to notice more media presentations which can add to one's ability to place science in a "real world" context for students.

o <u>Accepting the Responsibility of Educational Leadership</u>. The status studies clearly show that most important curriculum decisions are made by teachers. These include the determination of course offerings, selection of textbooks and development of classroom activities. Thus, if teachers are convinced that the actual thrust of the science curriculum is not consistent with the needs of most students, it is possible to change the situation. Large changes will probably require that a good case be made to administrators and citizens, but changes can be made. Teachers probably have more ability to cause such changes to happen than any other group of people, and it is important to realize that teachers are the most important authors of educational policy.

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X. PRIORITIES FOR IMPROVING SCIENCE EDUCATION IN THE UNITED STATES

An Epilogue

Project Synthesis provides a unique opportunity for focusing upon current needs and corrective actions in science education in America during the remaining years of the twentieth century. The new challenges which need immediate attention are:

1. A major redefinition and reformulation of goals for science education; a new rationale, a new focus, a new statement of purpose are needed. These new goals must take into account the fact that students today will soon be operating as adults in a society which is even more technologically-oriented than at present; they will be participating as citizens in important science-related societal decisions. Almost total concern for the academic preparation goal, as is currently the case, is a limiting view of school science.

2. A new conceptualization of the science curriculum to meet new goals; redesigns of courses, course sequences/articulation, and discipline alliances are needed. The new curricula should include components of science not currently defined and/or used in school. Direct student experiences, technology, personal and societal concerns should be foci.

3. New programs and procedures for the preparation, certification, assignment, and the continuing education of teachers; planned changes, continuing growth, and systems for peer support are needed. With new goals and a new conceptualization of the science curriculum, teachers must have assistance if their meaning is to be internalized. Without attention to inservice education, new directions and new views of the curriculum cannot succeed.

4. New materials to exemplify new philosophy, new curriculum structure, new teacher strategies; exemplars of the new directions, i.e., spécific materials for use with learners, are constantly needed. They provide concrete examples for use in moving in such new directions.

5. A means for translating new research findings into programs for affecting practice; a profession must have a philosophic basis, a research base, a means for changes to occur based on new information. Separation of researcher from practitioner is a major problem in science education: all facets of the profession must work in concert for major progress to occur.

6. Renewed attention to the significance of evaluation in science education; self-assessment strategies, questioning attitudes, massing evidence for reaching decisions on instruction and student outcomes are basic needs. Without such [illegible], observations, and judgments, future changes will be [illegible] hazard occurrences.

7. Much greater attention to development of systems for implementation and support for exemplary teaching and programs at the local level; current erosion of support systems for stimulating change and improvement in science education at all levels is a major problem.