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**ABSTRACT**

This report describes the rationale, methodology, findings, and recommendations of "Project Synthesis," a research study which synthesized and interpreted information found in six selected databases. Using a discrepancy model, five focus groups (biological sciences, physical sciences, inquiry, elementary school science, and science/technology and society) each determined desired (ideal) states, described actual states, and offered recommendations based on discrepancies between the actual and desired states in their particular area of science education. Chapter 1 contains an overview and summary of the project and five focus groups. Chapters 2-4 are focused on the desired biology program, actual biology programs, and discrepancies between the actual and desired biology programs, including information gaps, needed research, and recommended solutions. The desired state of physical science programs, actual state of physical science programs, and status and needs of precollege physical science education are considered in Chapters 5-7. The desired state of inquiry, status of inquiry, and an analysis of and recommendations for the role of inquiry in science education are discussed in Chapters 8-10. The status and needs of science education in the elementary grades and the interaction of science/technology and society and its place in precollege science education are considered in Chapters 11 and 12 respectively. (JN)

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**PROJECT SYNTHESIS:**

**An Interpretive Consolidation of Research  
Identifying Needs in Natural Science Education**

Final Report

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**PROJECT SYNTHESIS - FINAL REPORT**

Project funded by  
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## PREFACE

Concern for the relevance and effectiveness of instruction is nothing new in education. In the past five years, however, the science education community has become increasingly concerned with such matters. While the impact of science and technology on our day-to-day lives can only be more obvious today than ever before, the value attached to traditional school science programs seems to be on the decline. In April of 1979, a headline in The New York Times summed up the situation, "Halcyon Days for Science are Over in the Schools - Post-Sputnik Fervor Wanes as 3-R's Gain."

A few years ago, the National Science Foundation funded some extensive studies of the status of science education. The interpretation of the wealth of data from these and other sources was the task of Project Synthesis. The purpose of this report is to describe the rationale, methodology, findings and recommendations of that project.

In what proved to be monumental undertaking, five different groups of educators participated, examining the data from varying perspectives. Chapter 1 of this report is an overall summary of the project. It consolidates much of the work of the five groups. Chapters 2 through 12 are the individual group reports.

This volume begins with an Overview and Summary (Chapter 1) and then presents the work of the five working teams. Chapters 2, 3 and 4 represent the work of the Biology team. Chapter 4 includes a brief summary of Chapters 2 and 3. Chapters 5, 6 and 7 represent the work of the Physical Science team, with a summary of Chapter 5 and 6 appearing in Chapter 7. Chapters 8, 9 and 10 represent the Inquiry team with Chapter 10 including a review of Chapters 8 and 9. Chapter 11 represents the work of the Elementary team, and Chapter 12, the Science-technology-society team. Each chapter carries its own table of contents and page numbering system.

References for our four major data sources have been abbreviated for simplicity. The works of Helgeson et al, National Assessment, Stake et al, and Weiss are referenced as "OSU", "NAEP", "CSSE", and "RTI". For OSU and RTI, numbers in references refer to page numbers. For CSSE, they represent chapter and page numbers, and for NAEP they represent specific test item numbers. In addition, references in Chapter 1 which represent quotes from other chapters in this book refer to the group, the chapter and the page; for example, Bio 3:4 references Chapter 3, page 4, which was written by the Biology group.

## ACKNOWLEDGMENTS

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:

Those who did the research on which this project was based. They include Robert E. Stake and Jack A. Easley and their case study team at the University of Illinois, Iris R. Weiss and her survey group, at Research Triangle Institute, Dr. Stanley L. Helgeson, Patricia E. Blosser and Robert W. Howe at Ohio State University, and David Wright, Jan Pearson, Barbara Ward, and Roy Forbes of National Assessment of Educational Progress.

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;

David Hawkins, Bentley Glass, Mary Budd Rowe, William Romey and Linda Ingison, who participated in early meetings to help determine some of the thrusts of our project, and Arlen Gullickson, who served as a facilitator and "trouble-shooter" for the project;

Glenda Moore and Mary Ann Gardner, who gave so willingly of their time and competence as project secretaries, and Sheri Harms and Jo Kearney who typed the final copy;

Stuart Kahl, Project Synthesis Associate Director, who accepted major project responsibilities throughout the duration of the project and "made everything happen";

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 on pages 1-8 and 1-9. This volume is the result 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.

CHAPTER I

PROJECT SYNTHESIS:  
EXECUTIVE SUMMARY AND OVERVIEW

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## PROJECT SYNTHESIS

## EXECUTIVE SUMMARY

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. We approached the task 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. We emerged from the process convinced that there is a major 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 students will take considerable coursework leading to careers in science. Goals which appear to be largely ignored include preparation for citizen participation in science/technology-related societal issues, preparation to utilize science in everyday life, and preparation for making career choices in science-related fields. Even where materials reflecting broad goals exist, their implementation seldom results in practices which reflect those broader goals.

This conclusion, if accepted by the education community, has massive implications for all activities related to science education. One major purpose of this report is to share the evidence we found, the ways we processed that evidence, and the lines of reasoning which have led to this conclusion. A second major purpose of this report is to suggest courses of action which can serve to improve the situation. Those suggestions emerged from an analysis of the problem and of certain contextual constraints illuminated by the data base.

It seems particularly ironic that science instruction is becoming less valued at a time when the urgency of science/technology-related issues is more apparent than ever in our society. A closer examination of existing science programs, however, makes this situation easier to understand.

During the elementary years, a child's exposure to instruction in science is minimal. During the remainder of one's precollege academic career, science programs are primarily dedicated to the presentation of the "pure" content of the various science disciplines largely free of personally or societally relevant contexts or applications, and largely devoid of opportunities to experience the sense of inquiry which lies at the heart of scientific endeavor. If one's concern is general education, the science curriculum in our schools is greatly deficient.

The usual science sequence in high school appears to be designed primarily for that small proportion of students who are likely to pursue science in college and thereafter. Even for those students, there is little science instruction which makes the connection between scientific knowledge and real world applications. The existing courses which do place greater emphasis on personal and societal relevance reach very few students, are often intended for the low ability students and are most susceptible to being discontinued due to a number of factors. An examination of the science programs in the middle school and junior high years reveals that those programs reflect the same purposes and implicit rationale as do the high school programs.

The concerns described above should not be interpreted narrowly. They do not refer only to curricular materials or just to course offerings. Instead they are representative of a systemic problem -- one resulting from a myriad of factors which tend to perpetuate an orientation to science education which neglects the needs of a large majority of the student population. Clearly, the underlying rationale for existing precollege science programs needs to be reexamined.

Recommendations for actions designed to reduce the mismatch between needs and practice fall largely into the following three areas.

Area 1: A Major Reexamination of Goals at All Levels and in All Disciplines

Goals of science education need to be examined for their consistency with each of the following factors:

- (a) the needs of individuals to utilize science in their own lives and to cope with an increasingly technological world;
- (b) the needs of an informed citizenry as it deals responsibly with science and technology related issues;
- (c) changes in emphasis within the various sciences;

- (d) the needs of students to make informed choices concerning their future careers and preparation for those careers;
- (e) psychological limitations stemming from students' developmental, intellectual and personality characteristics;
- (f) students' individual goals;
- (g) community standards and values.

The need for all groups concerned with science education to reexamine goals is especially critical. Current "de facto" goals, as discerned from curriculum materials, classroom practices, laboratory experiences, student achievement, and other indicators seemed largely out of step with the factors listed above.

Area 2: Identification and/or Development of Programs Which Reflect Broader Goals Consistent With the Factors Listed in Area 1 Above

In addition to a need for reevaluating goals and establishing viable change mechanisms, there is also a need for the identification, revision and/or development of curriculum materials, especially at the junior and senior high school levels. In some areas (e.g., elementary school), appropriate programs exist, but need to be identified and implemented. Strategies for meeting these needs will vary.

Area 3: An Increased Emphasis on Professional Leadership and Support at the Local Level

The fact that effective change does not occur simply as a result of development and one-way dissemination has been well substantiated during the last twenty years. Thus, the reexamination of goals recommended above and consequent program changes can occur only with the help of strong leadership and support services, in-service education and community involvement at the local level. There is a need for considerable research and development which can lead to effective mechanisms for change in science education at the local level and a need for material and human resources which can put those mechanisms into action. Local adoption or development of innovative materials are unlikely to result in significant improvements unless they are accompanied by substantial support of implementation activities.

### Structure of the Study

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 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 below were designed to meet these conceptual requirements.

#### The Data Base

Recently, four comprehensive data bases have emerged which constitute an extremely rich resource for science education. These data bases include three studies funded by the National Science Foundation (NSF) and 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" (Stake and Easley, 1977), 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 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 provided 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, and the study was expanded to include an analysis of the most widely used science texts as identified by the RTI survey (Weiss, 1978). 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.

### The Focus Groups

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. Although these categories are not mutually exclusive, they do serve to reflect important areas of interest in science education.

Project Synthesis was very much a human endeavor calling upon the intellect, judgment and experience of a number of persons associated with science education. It seems important to list those persons as each of them certainly became a part of the "structure" of the study. The members of those groups are listed below:

<u>Focus Group</u>	<u>Participant</u>	<u>Position</u>
Biological Science	Paul DeHart Hurd (Chairperson)	Professor Emeritus of Education, Stanford University
	Rodger W. Bybee	Assistant Professor of Education, Carleton College
	Jane Butler Kahle	Associate Professor of Education and Biological Sciences, Purdue University
	Robert E. Yager	Professor of Education, University of Iowa
Physical Science	Ronald D. Anderson (Chairperson)	Professor of Education, University of Colorado
	Audrey B. Champagne	Associate Professor of Education & Research Associate, Learning Research & Development Center, University of Pittsburgh

<u>Focus Group</u>	<u>Participant</u>	<u>Position</u>
Physical Science (continued)	Richard J. Merrill	Curriculum Specialist, Mt. Diablo Unified School District, Concord, California
	Eric D. Miller	Curriculum Assistant & Instructor, Boulder Valley Schools, Colorado
	Lester G. Paldy	University Dean for Continuing & Developing Education at State University of New York at Stony Brook
Science/Technology and Society	Emil Joseph Piel (Chairperson)	Professor of Engineering, State University of New York at Stony Brook
	Thomas Brown	Private Consultant, Ithaca, New York
	David H. Ost	Professor of Biology, California State College
	Douglas S. Reynolds	Associate, Bureau of Science Education, New York State Department of Education
Inquiry	Wayne W. Welch (Chairperson)	Professor of Educational Psychology, University of Minnesota
	Glen S. Aikenhead	Professor of Education, University of Saskatchewan
	Leopold E. Klopfer	Associate Professor of Education & Research Associate, Learning Research & Development Center, University of Pittsburgh
	James T. Robinson	Staff Associate, Biological Sciences Curriculum Study
Elementary School Science	Harold Pratt (Chairperson)	Coordinator of Science, Jefferson County Schools, Colorado
	David P. Butts	Chairperson, Department of Science Education, University of Georgia

<u>Focus Group</u>	<u>Participant</u>	<u>Position</u>
Elementary School Science (con- tinued)	Roger T. Johnson	Associate Professor in Curriculum and Instruction (Science & Elementary Edu- cation), University of Minnesota
	Alice J. Moses	Elementary Science Teacher, University of Chicago Laboratory Schools

### Philosophic Perspectives

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 logically 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 for the goal clusters to 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 conceptual coherence 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 goal 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 joined us in the second meeting of group leaders. The goal clusters as described in this report and as operationalized by each focus group served as perspectives for much of the project work. The four 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 briefly here, and in more detail in later sections.

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 must also 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.

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 easily related to specific decisions about one's own life or about societal issues yet which are necessary for any further study of science. (This goal cluster is referred to as "fundamental knowledge" in some of the focus group reports. Data interpretation after the original definition of goal clusters lent itself better to the descriptor "academic preparation".)

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. Students should also gain an understanding of the interests, experiences and educational preparation which are usually associated with those careers.

#### The Domain of the Study

The data base used in Project Synthesis addressed many elements of the educational process. Since much of the data was categorized according to these elements, they also served as an organizer for the synthesis process. Some of the elements of that domain included:

Student Outcomes/Objectives

Program and Curriculum Characteristics

Program and Curriculum Dissemination/Adoption

Program and Curriculum Implementation including:

Exposure (course offerings, enrollments, requirements, time allotments)

Teacher characteristics (training, certification, personality characteristics)

Classroom practice (methodology, facilities/equipment, materials, media)

Student characteristics

Evaluation

### Stages of the Study

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 we would seek in the very large data base. Largely, that definition consisted of stating in operational terms the conditions one might expect to find in science education as evidence that it was succeeding, with regard to each of the four goal clusters and to other characteristics defined by the focus groups. 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", as 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 during its objectives development activities 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 at 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 major goals. These domain definitions can be found in each of the focus group reports, and are suggested reading for two reasons. First, they will provide the reader a clearer understanding of the perspectives from which the data were addressed, and second, they can serve as a useful point of departure for future reexamination of science education goals.

During Phase I an unanticipated source of information regarding the status quo in science education began to emerge. Our own 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 we were often breaking new ground in documenting the relevance of particular topics and processes for individuals and for society as a whole. We also became painfully aware that most of us 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 with some sense of accomplishment. This task had considerable effect on the mind-set with which we attacked the data.

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 and earth science, and technology), than with respect to science education at the elementary level or to the general domain of inquiry. For that reason, the activities of the elementary and inquiry groups tended to be directed toward general areas which did not always reflect distinctions among specific goal clusters.

As discussed earlier, the purpose of Phase I was to describe the conditions one would expect to find if the major goals of science education were being met. In the following sections, the desired conditions identified by the five focus groups are discussed. They are organized into subsections of "Learning Outcomes", "Curriculum Program Characteristics", "Dissemination and Adoption", "Course Offerings and Enrollments", "Teacher Characteristics and Classroom Practices" and "Testing and Evaluation".

brief summary of common elements from across the five focus group reports. More detailed descriptions and rationale are found in the individual group reports, along with treatment of specific areas of special interest to each focus group.

## Desirable Learning Outcomes

### Learning Outcomes for Personal Needs Goals.

Biology and life science classes which emphasize the personal needs goal would stress many areas that apply to all of us in everyday life. They include concepts and topics such as: basic concepts of human genetics, as related to birth defects, genetic diseases, and genetic counseling and

interrelationships between biological and cultural evolution and the effects of those factors on our individual life styles and behavior; the elements of nutrition as they apply to our individual diets, and the effects of inadequate diets on pre-natal nutrition, mental health and general health; the effects of environment, experience, age, sex, hormones and drugs on human behavior; the biology of reproduction and the uniqueness of human sexuality; the influence of nutrition, training, exercise, and other factors on bodily growth and function; and stages of human development from birth to death (Bio 2:6).

In examining a physical science program which did indeed pursue the "personal needs" goal, one would expect to find attention to common applications of science principles, such as the use of thermostats, air conditioners, evaporative coolers, heat pumps, common insulating materials; physics of internal combustion engines; common hydraulic applications (e.g., power steering and brake systems); energy requirements of commonly used devices; effects of various kinds of radiation on people; principles for shielding from radiation; common dangerous chemicals; effect of geological and climatic factors (floods, earthquakes, high winds, etc.) on the location and design of homes; effect of temperature on air pressure in tires; etc. (Phys 5:7).

Inquiry skills and behaviors which represent the personal needs goal include: monitoring health by measuring body indicators such as blood pressures, heartbeat, temperature, etc.; recognizing the limits of scientific knowledge and inquiry as applied to personal life; defining personal problems in solvable terms and seeking information necessary for their solution or resolution; identifying and seeking scientific information necessary for behavioral decisions such as deciding whether to smoke cigarettes, use drugs, ride motorcycles without a helmet, etc.; formulating and testing hypotheses which can lead to the solution of a personal problem (Inq 8:9).

Topics and learnings identified by Science/Technology/Society Group as being consistent with the personal needs goal include: personal decision making regarding the use of energy and natural resources; understanding the effect of technological developments on family units, personal transportation and health care; understanding of personal effects of human engineering developments in birth control, organ transplants and behavioral modification; understanding of ways in which personal behaviors affect the environment, in both the short run and long run; an understanding of research in space exploration and national

defense, including positive spinoffs which benefit people in their everyday lives; ability to apply systems approaches to individual problem solving (STS 12: 4).

Topics important for elementary children include personal health, knowledge of personal and physical self, skills for gathering information for personal use, recognition and acceptance of individual uniqueness, recognition that their lives influence the environment, and awareness and knowledge of constancies in themselves (Elem 11:10).

#### Learning Outcomes for Societal Goals.

Biology and life science classes which emphasize the societal goal would stress concepts and topics such as: technological gains through biological research; application of genetic principles in improvements of plants and animals; bioethical issues involved in genetic manipulation of human and other life forms; the possibility, advantages and disadvantages of controlling human evolution; worldwide problems of malnutrition and the effects of social patterns, life styles, advertising, research, etc., on the problems; widespread effects of drugs, chemicals, territorialism, human and natural environments and human values, etc., on group behavior; problems of population growth and factors which affect it; the need to preserve living species and other natural resources; the way achievements in biology affect the human life cycle; the nature of possible environmental factors which could lead to death of the human species (Bio 2:8).

Physical and earth science courses which pursue societal goals would include topics and concepts such as: limitations and potentials of various energy sources; origins and limitations of water, mineral and other natural resources; applications of physical principles, such as the laws of thermodynamics which place limitations on the production of energy; potentials and comparative advantages of fusion and fission technologies; effects of human activities on global climatic factors such as polar ice caps, sea level, ozone layer, rainfall patterns, acid rain, etc.; the chemistry of phosphates, nitrates and other chemical pollutants; the effects of physical interventions on all natural systems (Phys 5:8).

Inquiry skills and behaviors consistent with the societal needs goals include: measuring the effects of personal actions which influence society (e.g.,

measuring heat loss from a home); interpreting data about societal problems and judging the implications for personal behavior, for example, the effects of limiting speeds to 55 m.p.h. on gas consumption; recognizing that scientific knowledge regarding societal issues change and therefore demand a different point of view consistent with new knowledge; determining the main issues of science-related societal problems and distinguishing between scientific and non-scientific evidence with respect to such problems; recognizing the need for considering alternative viewpoints regarding societal issues and identification of appropriate evidence for making decisions regarding such issues (Inq 8:11).

The Science/Technology/Society focus group identified eight areas with which students now in school would most likely be concerned during the remainder of their lives. Those eight areas and a few of the concepts and topics they represent are: Energy - the import and implications of increasingly rapid growth of energy use throughout the world; Population - the effects of technological development on population growth, the nature and mathematics of exponential population growth and its effect on all societies; Human Engineering - the increasing implications of human-machine interactions on human behavior and machine design; Environmental Quality - the effect of personal and societal decisions on all aspects of the environment, and the necessary skills to make such decisions intelligently; Utilization of Natural Resources - the effects of personal and group decisions and behaviors on our supply of basic resources; Space Research and National Defense - the potential, costs and spinoffs from huge spending programs; Sociology and Technology - the effects of sociological and psychological constraints on technological developments; Effects of Technological Developments - the potential, limitations, dangers and side effects of current and expected technological developments such as weather control, earthquake prediction, test tube babies, genetic engineering, nuclear energy, etc. (STS 12:11).

#### Learning Outcomes for the Academic Preparation Goal.

Biological and life science classes which emphasize the academic preparation goal would include topics and concepts such as: basic laws and facts of genetics; evolution in structure and function; adaptation and environment; classes of foods and food supplements and their biological functions;

similarities and differences of behavioral patterns across species; processes of sexual and asexual reproduction and modification of genetic patterns through reproduction; the relationships between principles of genetics in sexual reproduction and the evolution of species; structural-functional relationships from the molecular level to the world biome level; the mechanism of photosynthesis and ultimate dependence of all life on photosynthesis; interactions among organisms; regulatory mechanisms within organisms; processes of respiration, digestion, circulation; chemical cycles of nitrogen, oxygen, carbon dioxide (Bio 2:11).

Physical and earth science courses which stress the academic preparation goal would treat topics and concepts such as: the nature of fundamental units of matter (molecules, atoms, subatomic particles, etc.); properties of elements and compounds and their interactions; principles of kinetics, dynamics, mechanics, physical geology, weather and climate; heat conductivity, kinetic-molecular theory, and gas laws; laws of thermodynamics, potential and kinetic energy, wave phenomena such as sound, light and electromagnetic radiation, static and current electricity and magnetism, solar radiation, and nuclear physics (Phys 5:9).

Inquiry skills and behaviors reflecting the academic preparation goal include: accurate observation and description of objects and phenomena using appropriate language; valuing data presented in the form of functional relationships in graphs, tables, equations, etc.; awareness of the changing nature of scientific explanations and understanding that theories are dealt with in terms of their utility rather than in terms of absolute truth; understanding of simple scientific statements and identification of evidence supporting or negating such statements; accurate and complete reporting of experimental data and openness to the criticisms of others concerning data and their interpretation (Inq 8:15).

At the elementary level, there is no one set of basic topics appropriate for science instruction. However, topics should be chosen (1) because they develop skills in generating, categorizing, quantifying, and interpreting information from the environment and (2) because they are interesting to students of a particular age (Elem 11:11).

Learning Outcomes for Career Choice Goals. 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 careers as scientists, engineers, technicians, equipment designers, computer programmers, lab assistants, as well as in jobs which apply scientific knowledge in agriculture, nutrition, medicine, sanitation, conservation, awareness that persons of both sexes, of all ethnic backgrounds, of wide ranging educational and ability levels and with various handicaps can and do obtain such jobs; awareness of the contributions persons in such jobs can and do 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, math 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 (Bio 2:13, Phys 5:9, Inq 8:19, Elem 11:11, STS 12:16).

#### Desirable Curriculum Program Characteristics

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 described and exemplified above. First and most obvious, topics such as those listed above 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 rest firmly 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. The rapid growth of scientific knowledge experienced during recent decades puts new demands on selection of curricular content. Each of the focus group reports describes specific ways in which topics could be selected and integrated into curricular programs. A summary of points common to all focus group reports appears here.

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 to have an understanding of the problems, the aspects of science which apply to the problems, and of the relationship between science and relevant problems. Students should 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 principles in the context of real world problems as suggested by our Biology Group. In this approach, science concepts are organized in terms of specific personal and societal issues. This is in contrast to biology courses organized to display the structure and logic of biology as a discipline (Bio 2:4).

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. Our Physical Science group suggested this second format as being appropriate for a major portion 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 actively participate 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; identification and application of principles related to the problem; 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 systematic decision-making models would be dealt with in an integrated fashion which stressed the interrelationships among them.

Another common element of programs in all areas would be the inclusion of fundamental aspects of science. Obviously, many basic learnings such as those described above under the academic preparation goal are important for

students planning science coursework leading to careers in science and engineering. It was also the conviction of our groups that such 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, etc. 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 way 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.

### Desirable Dissemination and Adoption Characteristics

The purpose of the previous section was to describe the general characteristics considered necessary for programs consistent with the four goal categories. The purpose of this section is to identify some characteristics of dissemination and adoption functions which appear necessary for the adoption of such goal-oriented programs.

One very important requirement of curriculum selection processes is serious consideration of various educational goals and philosophies, and the subsequent identification of classes and examples of learner outcomes and curricular characteristics consistent with those goals and philosophies. Another important characteristic of curriculum decision making is the assessment of needs of the various segments of the student population. These needs depend on student age, cognitive development, interests and probable adult roles. Although educators may be best able to answer questions of how to achieve particular goals, the determination of broad educational goals and philosophies is the responsibility of the entire community. Thus, it is important that community, parent and student voices be heard during the curriculum selection process, because all educational programs carry implicit goals and philosophies with them.

Another important condition for intelligent curriculum adoption is knowledge on the part of curriculum decision makers of the various programs available, and of the emphasis of those programs with respect to broad goals of the school system. If positive change is to occur, it is especially important that the decision makers be aware of new and innovative materials and of the philosophic rationale reflected by those materials.

A final requirement of decision processes in the adoption of curriculum programs which reflect shifts in goal emphasis is the existence of adequate support for teachers. It is necessary that teachers receive orientation regarding the philosophic rationale underlying adopted programs, learn the new teaching methods required of new programs, receive support for materials and supplies dictated by the new programs, and generally have some incentive for the additional time and effort required in implementing new programs.

### Course Offerings and Enrollments

It is possible to describe the general nature of course offerings and enrollments one would expect to find as indicators of emphasis on each of the major purposes of science education. As the personal, societal and career choice goals are relevant to students of all types (i.e., are important in "general" education), course offerings reflecting those goals would logically have the following characteristics:

1. They would attract enrollments of all types of students, including those bound for college and technical careers, college-bound students not entering technical areas and non-college-bound students.
2. As suggested earlier, basic science principles and concepts would be presented in a context which stressed their applicability to common situations in the immediate environment of most students, to important science/technology-related societal issues and to the careers associated with various topics.
3. Such courses would exist for students at all grade levels. Courses with societal, personal and career choice emphasis would have especially large enrollments at grades 11 and 12. This is because of the emerging social consciousness of students at that age, and also because of the emerging sense of need to be prepared for independent decision making as adults.
4. To the extent that such courses enrolled potential leaders in non-technical fields (e.g., those planning college majors in the social sciences, business, and law) they would especially stress the interaction between science, society and technology.
5. Courses attracting non-college-bound student groups would stress the application of science most likely to be encountered in daily life.
6. The course materials for use by general student populations would reflect the limitations of many students in reading ability and mathematical background. Additionally, the development of reading and mathematical skills would generally be secondary goals for such courses, not the primary goals.
7. Laboratory activities would utilize "real world" materials, and situations related to personal, societal and career choice decisions.

Courses which reflect the goal of academic preparation for further coursework leading to careers in the sciences (the academic preparation goal) might be expected to have the following characteristics:

1. They would tend to stress science principles in a formal "structure of the discipline" context.
2. They would expose students to technical terms and theory likely to be encountered in later academic courses.
3. They would enroll students of high academic ability.
4. Reading ability and mathematical sophistication required of students would be "above average."
5. Laboratory experiences would tend to reflect the tools of scientists and questions of interest to scientists.

One should keep in mind that the special group of students for which such courses are appropriate have equally as much need for the type of course described earlier as being appropriate for the general populations.

#### Teacher Characteristics and Practices

Ultimately, the degree to which any educational program achieves its goals depends upon classroom teachers. In all teaching disciplines we need teachers 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 important goals of science education 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 contribution 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 focus 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 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 can 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 students in the locale in which the students live, and develop learning experiences 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 (Bio 4:11, 12). Classes would utilize group investigative 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 (Inq 10:17). 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 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 ideally resolve issues.

Teacher characteristics associated with academic preparation goals 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-generating 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. It is unrealistic to expect students to interpret, apply, evaluate and analyze information if their only learning experiences are in acquiring and regurgitating information.

### Testing and Evaluation

There are several ways in which testing and evaluation activities can contribute to educational programs which are designed to achieve goals such as those described earlier in this section. Tests developed to guide policy decisions at the district, state or national level can be most useful if they broadly represent all the major goals of science education. They also should

represent all aspects of science, reflecting not only recall of information, but also the skills of acquiring information via inquiry, and the skills of processing and utilizing information via analysis, interpretations and decision making. Such broad based tests can then be applied diagnostically to science programs as a whole in determining areas of greatest need, as reflected by student performance. At the classroom level, tests can be employed to diagnose student needs and to prescribe specific instruction to meet those needs. It seems reasonable to expect science teachers to use tests empirically and rationally; i.e., to collect the information needed to make day-to-day instructional decisions and to utilize that information in making large curriculum decisions.

### Phase II: Determining the Status of Science Education

The task at 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 above. 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, Technology and Elementary groups analyzed widely used texts (as identified by the RTI survey) with respect to those questions raised in Phase I.

Much of the group meeting time was spent merging the information and interpretations of the individuals into group-approved statements regarding status. Merging raw information about many elements of the educational system into relatively concise interpretive 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 out 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. Thus, the specific quotes found in the focus group reports often represent only a small sample of the many bits of evidence discussed in the development of particular interpretations.

### Overview of Phase II Findings

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 with the exception of Biology, the status of science courses is declining. This low priority results in a lack of support for science instruction at the local level.
2. 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.
3. The entire domain of inquiry receives very little attention, and appears to be in a state of decline.
4. The domain of Science, Technology, and Society (STS) as defined by the STS focus group is systematically excluded from precollege science education at all levels and in all disciplines. Although technology-related curriculum materials have been developed, they have not been successfully implemented on an appreciable scale.
5. The typical science experience of most elementary students is very limited. It usually consists of reading and memorizing facts related to concepts too abstract to be well understood by students. Excellent materials are available nationally, and many good materials have been developed by local districts. However, implementation efforts have generally failed to get good programs established in classrooms.

Data and interpretations which support the above conclusions, as well as other conclusions of specific interest to each focus group, are presented in each of the focus group reports. A summary of those arguments is presented here.

### Priority Status of Science Education in Schools

As stated 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 recognize the need for minimal competency in science. School superintendents (CSSE 18:85) and parents think any trend away from science education should be reversed (CSSE 17:20, 18:35). There was considerable support from all groups for a federal role in improvement of science education (CSSE 18:100) and there is some evidence that younger students at least (57%), 'wish they had more science in school' (NAEP, C01-E05-B). Most states require at least one year of science (RTI 25).

"Although there seem to be general positive attitudes about the value of science education, there do not appear to be strong forces working to promote science education (CSSE 19:10). School superintendents do not appear to give science high priority (CSSE 17:20); state science requirements are declining (OSU 121), and there is some evidence that science instruction is being deemphasized as a result of the back-to-basics movement (CSSE 5:28, 17:19, 18:55) and vocational education. Unfortunately, it appears many people regard the basics as being the 3R's and not science. Although teachers generally express positive attitudes about the value of science, 'a substantial number of teachers do not enjoy teaching science, do not enjoy science themselves, do not take science-related coursework after they graduate, and do not study science on their own' (OSU 122). In what may (or may not) have been an extreme case, one elementary principal said, 'I've had to almost force someone to put the science kit in their classes. No one wanted to have anything to do with it' (CSSE 10:19)" (Inq 9:5).

The lack of contextual 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 (OSU 122; CSSE B:4, 19:25-26, 18:41, 6:23). About half of the superintendents and science supervisors felt budget cuts had seriously affected the science curricula, but fewer than 20 percent felt that such cuts had resulted in 'more teaching from textbook, less with project and lab work' (CSSE 18:41)" (Inq 9:6). The effects of budget limitations on teacher in-service, facilities, materials and organizational support are discussed in later sections.

#### Status with Respect to Four Major Goals

Centrality of Textbooks. The focus groups were generally convinced by the data sources that textbooks exert an overwhelming dominance over the science learning experience (Bio 3:19-21, 35, 36; Elem 11:14; Phys 7:19, 20; STS 12:20). Evidence to support this conclusion were apparent in all the data sources. The CSSE case studies found teachers to rely on texts (CSSE 19:6), reported data that 90 to 95 percent of 12,000 teachers surveyed indicated they used texts 90 percent of the time (CSSE 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" (CSSE 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 RTI survey to be used most widely (RTI B44-B45). Generally, they were inspected to determine if they reflected the desirable program characteristics identified in Phase I (Elem 11:14-17; Phys 7:21, 22; Bio 3:13-21; STS 12:20).

Goal Emphasis in Textbooks. Generally, the most widely used texts in all disciplines and at all levels were largely devoid of the characteristics representative of goals related to personal utility, societal issues and career choice, as described in an earlier section. 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. Additionally, there was virtually no treatment of the relationship between traditional science concepts and the personal, societal or career choice decision facing students.

The Physical Science Group found, "The net result of the sample analysis is that little attention is given to Goal Clusters I, II and IV (personal, societal and career choice) 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" (Phys 7:21). One notable exception to this rule was the NSF-sponsored Project Physics course, which "attempts to portray physics in a historical and humanistic context." The Physical Science Group goes on to report, "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."

The Biology Group summarized its analysis of existing junior and senior high texts in this way: ". . . discreet 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. There is little attention given to personal needs and social issues related to biology" (Bio 3:21).

The Elementary Group summarized its analysis of the four most widely used elementary series by saying, "Content related to student needs was primarily limited to portions of chapters on health-related information about the human body . . . given explicit emphasis at the primary level, but missing or only implied at the intermediate level. The relationship of science to society

is illustrated only occasionally in (widely used) texts. Content which clearly addresses the human side of scientists . . . was limited to a few short biographies in some texts, but they were either absent or easily avoided in most programs; the obvious conclusion was that this goal cluster was generally neglected in all texts examined. The content is largely structured and presented with no intent to encourage students to generate either observations or interpretations of their observations" (Elem 11:14-16).

The Science-Technology-Society Group summarized the treatment of their entire domain in two simple sentences: "Teachers rely on texts for their course content. There is little or nothing of STS in presently available texts." By "STS the group was referring to those areas of concern outlined earlier in this paper (STS 12:20).

To better illustrate the nature of the 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 learnings about insects which might seem particularly useful in people's everyday lives include: the value of insects in our yards and gardens, e.g., bees pollinating fruit trees, earthworms aerating the soil, 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 mosquitoes and other insects; the apparent necessity for the use of insecticides in intensive agriculture, the harmful environmental side effects of insecticides, and 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 would be 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 entomologists who specialize in forest management. However, when we look at the most widely used biology textbook, we find these topics virtually ignored. What we do find 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.

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 texts 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. We considered the failure to make such insertions as evidence that the ignored goals were given virtually no priority by those who prepared these popular texts.

Some texts 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 identified above. Widely used physical science texts developed by NSF 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 commercially available texts. For example, two widely used texts in this category, Introductory Physical Science and ISCS 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 phenomena.

It is important to note here that we are speaking of widely used texts, as determined by the RTI survey. It is possible that a thorough review of all materials available would identify texts with much broader goals. The Elementary Group surveyed three categories of texts. The first category, "widely used texts", fits the general description stated above. A second category, "NSF funded curriculum", and a third category of "new generation" texts are

reviewed in their report (Elem 11:14). These other two categories of texts, 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 (Bio 2:18) 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 texts. The Science-Technology-Society Group also identified materials dealing with technology concepts, but found that they were virtually unknown to science teachers (STS 12:21).

### Status of Dissemination and Adoption

The processes by which information about curriculum gets to local decision makers, the decision processes which result in adoption, and the activities directed towards the implementation of new curricula, all are extremely important factors in the practice of science education. Although the data base did not directly address these phenomena in detail, there is indirect evidence which sheds much light in this direction. Some of the major recommendations in the final section of this paper are related to studying this whole area in greater detail.

Teachers appear to be the primary decision makers in the selection and use of curricular materials (RTI 99); teachers' involvement in this process, either as individuals or in 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 (RTI, B48-B55).

As noted by 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 (RTI 152, Table 73)" (Inq 9:7).

The Physical Science Group explained, "Information about new materials and programs reaches teachers through a wide variety of means. The popular sources include professional meetings, journals, publishers' representatives,

teachers, principals, courses and NSF institutes. Other teachers and college courses are the most frequently used sources and local inservice programs are reported to be useful sources by elementary teachers but not by secondary teachers. About half of grades 10-12 teachers, one-third of grades 7-9 science teachers, and 80 percent of state science supervisors indicated they had participated in an NSF institute. Teachers who had participated in NSF institutes recalled them with much pleasure and believed them to be of considerable value (RTI 71-76).

"In spite of the wide variety of means of dissemination, teachers' perceptions are that their needs are not completely met in this regard. At all grade levels the list of their needs is headed by 'learning new teaching methods' and 'obtaining information about instructional materials' (RTI B-106-115). Forty-three percent of teachers indicated they do not receive adequate assistance in obtaining information about instructional materials (RTI 148)" (Phys 7:22).

One indicator of the information base from which teachers make decisions about curriculum is their knowledge of various NSF-funded curriculum, as reported in the RTI survey (Table B-20). The percentage of teachers who reported they had seen or used certain NSF curricular materials was surprisingly small in many cases. For example, only 27 to 33 percent of elementary teachers reported having seen Science - A Process Approach (S-APA), 32 to 41 percent had seen Science Curriculum Improvement Study (SCIS) materials, 6 to 11 percent had seen Unified Science and Mathematics for Elementary Schools (USMES), and 32 to 42 percent had seen Elementary Science Study (ESS) materials. These numbers are probably somewhat exaggerated, as 9 to 14 percent of the same teachers reported having seen or used Science Explorations for the Future, a fictitious curriculum material. Tempering the self-report data with this evidence of slight exaggeration, it appears safe to estimate that from two-thirds to three-fourths of all elementary teachers have not heard of each of these specific NSF-funded materials.

At the secondary level, similar data have somewhat less meaning, because the curricular materials are available within specific science disciplines and one would not logically expect large numbers of physical science teachers, for example, to be aware of a wide variety of biology materials. Thus, the fact that 78 percent of grades 10-12 teachers reported they had seen Biological Science: An Ecological Approach (BSCS Green) appears to indicate a rather

widespread awareness of that popular NSF series. The 57 percent of 10-12 teachers who had seen CHEM Study materials, the 69 percent who had seen IPS, the 53 percent who had seen PSSC Physics and the 49 percent who had seen Harvard Project Physics are also indicative that these materials are widely known. By contrast, the data on two technology-related curricula were extremely disappointing. Only 14 percent of grades 10-12 teachers reported having seen the Technology-Energy-Environment materials developed by the Engineering Concepts Curriculum Project (ECCP) and only 18 percent reported having seen The Man-Made World (ECCP) materials. Knowing that 13 percent of grades 10-12 teachers reported having seen or used a fictitious curriculum used as a validity check, we come to the conclusion that probably 5 percent or fewer of all grades 10-12 teachers know of two leading NSF curricula specifically designed to present topics relating science, technology and society.

At the junior high level, awareness of NSF-developed materials was somewhat better than at the elementary level, but not as good as at the high school level. Percentages of grades 7-9 teachers who reported having seen specific materials included: Introductory Physical Science (IPS), 62 percent; Investigating the Earth (ESCP), 52 percent; and Probing the Natural World (ISCS), 46 percent. Once again, these numbers should be tempered by the fact that 5 percent of grades 7-9 teachers reported having seen fictitious materials.

In summary, it appears that about one-fourth to one-third of elementary teachers had seen more popular NSF-funded innovative science materials, about one half of junior high teachers had seen them, and probably most high school teachers had seen such materials in their particular discipline. However, apparently only about 5 percent of the high school science teachers had seen major technology-related materials.

Although much remains to be done to inform elementary teachers of innovative materials and to inform secondary teachers of materials developed around science-technology-society related topics, the fact that millions of teachers have seen the more popular NSF-funded curricula indicates that a concerted, nationwide program-awareness effort can have a major impact on teachers' knowledge of innovative materials.

#### Leadership and Coordination Functions.

Although the data base primarily reflected status indicators rather than change indicators, the impression conveyed is that the general nature of

science education has changed very little in the last few decades. In fact, the materials and classroom practices reported often appeared quite similar to those experienced by Synthesis consultants during their own years as students twenty to forty years ago. The OSU literature review (16, 93) found evidence of remarkably stable teaching practices over the past twenty-five years.

In light of this apparent lack of change, questions about leadership functions naturally arise. Is there a sufficient leadership function in science education? Has this function worked in the direction of change, has it been a restraining factor, or has it simply had little impact?

At the local level, there are few designated leaders with sufficient time to affect major changes in teacher decisions and behavior. The Elementary Group concluded that "chances are two out of three that no one is available in the school or district to provide the (elementary) teacher with any suggestions on new techniques or materials (in science)." Also, elementary principals feel less competent to provide leadership in science than in social studies, language arts or mathematics (RTI 48). This situation is compounded by the fact that at the local level, only 20 percent of the districts have as many as one person spending 75 percent time in science coordination (RTI 39).

The Physical Science Group found it notable that "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 teacher and administrators and other resource personnel, and that the teacher seldom was personally in touch with a curriculum coordinator per se. . . . There are few people outside the classroom to provide quality control for the curriculum and assist teachers with pedagogical problems" (CSSE 16:43). This conclusion is supported by teachers at all levels who report the areas of "learning new teaching methods" and "obtaining information about instructional materials" as being those in which they receive the least adequate assistance (RTI B-106-115).

At the state level, the leadership picture is also bleak. Only 55 percent of the states have as many as one person spending seventy-five percent of his time in statewide coordination of science (RTI 34). In this respect, science ranks slightly behind social studies and mathematics (RTI 34) and probably far behind other areas such as reading, vocational education and special education. Across the nation, expenditures for statewide coordination activities in science average \$41,500.00 per state, which also ranks behind mathematics and social studies (RTI 35). Thus, less than 10 cents is spent for

each student enrolled in a science class on state level activities in science coordination.

At the national level, the National Science Foundation has been the prime mover and recognized leader in curriculum development, curriculum dissemination and teacher training through NSF-sponsored institutes. One good indicator of the NSF impact is in the number of classrooms using NSF-supported curricular materials.

The RTI survey collected information on the "Most Commonly Used Science Textbooks/Programs By Grade Range" (RTI B-44, B-45). Table I below categorizes those data into NSF-sponsored and non-NSF-sponsored curricula. As can be seen, NSF-sponsored materials are the primary text in at least 8 percent, 11 percent, 16 percent and 14 percent of classrooms at grades K-3, 4-6, 7-9 and 10-12, respectively.

Table I

Percentage of Classrooms Using  
NSF and Non-NSF Materials, by Grade Range

Widely Used Texts*	Grade Range			
	K-3	4-6	7-9	10-12
NSF	8%	16%	11%	14%
Non-NSF	<u>34%</u>	<u>51%</u>	<u>37%</u>	<u>37%</u>
Total percentage of classrooms using "widely used texts"	42%	67%	48%	51%

\*"Widely used texts" include those used in 2 percent or more of science classrooms at a given level.

Information derived from course offering data (RTI 53) indicates that at the time of the survey, there were approximately eleven million students enrolled in science classes in grades 7-9 and six million in grades 10-12. The number of students enrolled in courses which use NSF materials is apparently at least 1.2 million<sup>1</sup> at grades 7-9, and .84 million at grades 10-12. Thus, a very conservative estimate is that over two million secondary students were using "widely used" NSF materials as their primary text at the time of the survey. Adding gross (but conservative estimates of one-half million at grades 1-3, one million at grades 4-6 and one-half million for students at all levels using NSF materials which did not make the "widely used" list, we arrive at a rough, probably conservative estimate that over four million students were using NSF-sponsored materials at the time of the survey.

There was considerable doubt in the minds of all focus groups regarding the fidelity of practice (especially regarding inquiry) to NSF intentions, and the numbers reported above represent a fairly small fraction of all U.S. students. Nevertheless, the NSF efforts had the result that over four million students per year used as their primary text those curricular programs judged by our groups to be richer conceptually than were the texts they replaced. Furthermore, it was a general consensus of the groups that many recent texts developed by private publishers have been strongly influenced by the NSF texts developed in the sixties.

Several factors make these results seem significant. The national curriculum development effort of the sixties was the largest ever mounted. The changes occurred despite the apparently strong factors in school systems which serve as obstacles to change. Finally, the new curricula were chosen by teachers and others who traditionally have had close contact with sales representatives selling more "traditional" texts.

It is important to remember that the NSF developments occurred largely as a response to fears that our production of scientists and engineers was falling short of national needs. Russia's launching of Sputnik increased the alarm and focused much attention on the shortage. Recollege programs, along

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<sup>1</sup>The term "at least" is used, because other NSF materials which did not appear on the "widely used" list were also in use. Note that the "widely used" texts above account for only about half of total text use.

with other NSF educational programs, were designed to alleviate that shortage. Partially due to these efforts, and partially due to natural labor-market forces, that shortage was alleviated.

In summary, it can be said that although the NSF efforts did not radically improve science education throughout the country, those efforts have resulted in the use of improved materials by over four million students per year, and they have demonstrated that concerted, national-level efforts can have a major impact on the materials used by significant numbers of classroom teachers.

### Course Offerings and Enrollments

When considering the status of science education with respect to the four goal clusters, inquiry, and the special problems of the elementary school, it is useful to consider a general quantitative overview of the exposure of students to science instruction K-12. From such an overview, it is possible to form generalizations about the success of science education in achieving some of the characteristics identified in Phase I.

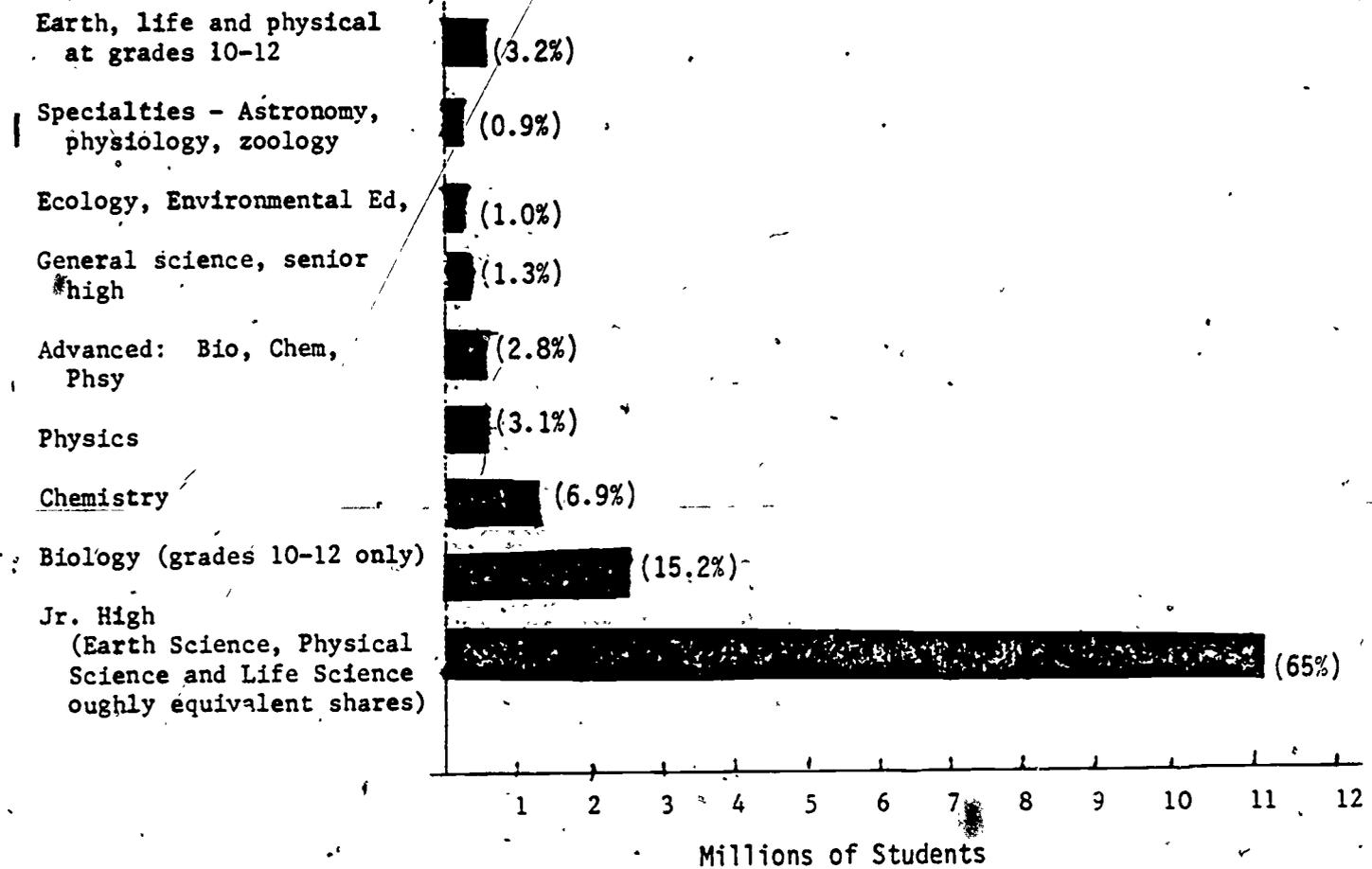
At grades K-3, teachers report spending an average of 19 minutes per day in science instruction. At grades 4-6, teachers report spending an average of 35 minutes per day in science instruction. In both cases, science ranks behind mathematics and social studies in reported instructional time. It is probable that there is some positive bias in these self reports, and that the actual instructional time is less than that reported. Although more classroom time for science would be desirable, quality factors (discussed later) appear to be the greater problem at the elementary level.

One useful way of examining student exposure to science instruction at the junior and senior high level is to consider the number of students enrolled in various types of science classes. It is possible to translate RTI secondary data into student enrollment terms with sufficient accuracy for our discussion here.

Exhibit A (adapted from information in the RTI report, Table 27) depicts student enrollment in the secondary schools (grades 7-12) both in terms of millions of students and in terms of percentages of the total secondary student enrollment. As can be seen by the exhibit, about 11.26 million students, or nearly two-thirds of the total secondary science enrollments in 1977 occurred in grades 7-9. About two-thirds of that grade 7-9 exposure was in General

## Exhibit A

Distribution of Total Secondary Science Student Enrollment Expressed in "Millions of Students", and in Terms of (Percentages) - 1977. A Total Enrollment of 17.6 Million Students is Represented



Science classes, and the remaining one-third was divided about equally among classes labeled Earth Science, Life Science and Physical Science. Although there are no data regarding the split within general science courses, our experience and our review of popular texts indicate that these courses are divided about equally among the earth, life and physical sciences.

Courses labeled "Biology", offered predominantly in the tenth grade, account for an additional 3.1 million students enrolled annually in secondary science. Thus, in grades 7-10, approximately 14.4 million (81 percent) of all secondary student exposure to science occurs. About half of that exposure is in the life science and biology categories, with the other half being devoted to the physical and earth sciences. Of the remaining 19 percent of secondary science exposure, most of which takes place in grades 11 and 12, 6.9 percent occurs in chemistry, 3.1 percent in physics, 2.8 percent in advanced biology, chemistry or physics courses, and about 1 percent in each of the remaining categories of general science, physical science, ecology-environmental science, and academic specialities (astronomy, physiology and zoology).

Several clear generalizations emerge from secondary enrollment data. First, at grades 11 and 12, enrollments and course offerings appear to largely preclude exposure of most students to science courses of any kind, and the 30 percent or so who do enroll in science classes are restricted to courses stressing the academic preparation goal. Second, enrollments at grades 7-10 indicate that the bulk (about 80 percent) of secondary science exposure occurs with general populations of students. Thus, with current enrollment patterns, the potential exists for pursuing any or all of the goals of science education for most students in grades 7-10. The study of textual materials and teacher practices, however, made it apparent that the academic preparation goal also dominates at grades 7-10, and that very little attention is given to course offerings designed to help general student populations to utilize the concepts or processes of science in their everyday lives, to deal intelligently with science and technology related societal issues, or to begin to make intelligent choices regarding careers in science or technology. Third, courses which stress interactions between science, technology and society (e.g., environmental/ecology courses which were the only ones registering in the survey) enroll extremely small percentages of students, and it is unlikely that many of our future leaders receive significant exposure in science classes to

problems related to the interface of science, technology and society.

### Status of Teacher Characteristics and Practices

Centrality of Teachers. Evidence cited in the previous section establishes teachers as the primary decision-makers in the selection of curricular materials. 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 (Bio 3:29; CSSE 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" (CSSE 12:5; Inq 9:7). This autonomy apparently encompasses teaching style, modes of presentation, selection of supplementary materials, determination of student activities, selection of tests, assignment of grades, and within limits set by the administration, the determination of out-of-school field trips, work experiences, etc.

Goals of Teachers. Teacher-made decisions in the areas suggested above operationalize the curriculum in ways which reflect the philosophies and goals teachers consider to be important, achievable, and within their domain of responsibility. Some extremely important questions thus emerge. What are the goals, philosophies and other factors which govern these decisions? How broadly based are they? How do they compare with the goals espoused by other science educators? What are the implications for the four goal clusters and for inquiry science? The data base at our disposal provided some interesting insight on these questions, and a summary of conclusions is presented here. This is also an area in which more research could be quite helpful to those intending to improve science education.

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 report. 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 CSSE observers as fitting within the general class of "socialization", (CSSE 16:3-26). Socialization goals include inculcating students with the work ethic; teaching students to learn from a text; paying attention to directions or presentations, carrying out assignments; preparation for tests; preparing for next year; observing the

These socialization goals apparently "take precedence over general study skills, general study skills over specific operations, and specific operations over subject matter" (CSSE 16:25). "Putting it in a nutshell, most teachers seemed to treat subject matter knowledge as evidence of, and subject matter as a means to the socialization of the individual in school" (CSSE 16:24). Of course, teachers were also concerned with goals related to science. "Teachers must juggle the expectations of the invisible, distant and mostly impersonal profession of science education and the local, powerful and relentless demand of teaching. The two roles do not necessarily conflict; but the latter usually overpowers and pre-empts the former" (CSSE 16:26).

The pre-eminence of "socialization" goals appears to explain much current practice in science education. For example, one finding of CSSE was that one "constant, across classrooms which varied in many other respects, was that instructional materials provided the conceptual structure for the instruction more than the teachers' or students' organization of thought about the subject matter. The principal reason for this now seems to us to be that the teachers' socialization goals -- especially preparing students for success in later schooling -- required that pupils learn to learn from materials" (CSSE 16:21). Our Inquiry Group concluded that "the socialization goal is manifested in activities stress authority and discipline; and for many teachers inquiry teaching is not conducted to these emphases. Classroom activities which appear to many teachers to enhance socialization include written homework assignments, classroom recitation and preparation for tests. Unstructured, open-ended activities without a 'single correct answer' appeared to detract from teacher pursuit of the socialization goals" (Inq 9:9).

Turning our attention from the socialization goal to goals representative of the four goal clusters and inquiry teaching, we come to the firm conclusion that teachers generally have a narrow perception of their responsibilities within these goals. The apparent primary goal of most science teachers appears to be that of learning "fundamental knowledge" which is necessary to prepare 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 the above conclusions is the almost total reliance on texts, and the nature of the texts themselves, as discussed in detail earlier, and in the focus group reports. The centrality of THE TEXTBOOK appears

to be an extremely important and powerful characteristic of classroom practice. For that reason, we quote at some length the conclusions drawn in Chapter 13 of the CSSE report, pages 59, 60, 65, 66. Those interested in reading more on the topic are urged to read all of Chapter 13 of that report.

The teacher was "arbiter much more than authority when it came to the curriculum. The source of knowledge authority was not so much the teacher—it was the textbook. Teachers were prepared to intercede, to explain, but the direct confrontation with knowledge for most students was with printed information statements. Teachers did it differently from classroom to classroom, but regularly there was deference to the textbook, or lab manual, or encyclopedia, map or chart. Knowing was not so much a matter of experiencing, even vicariously (self-knowledge was not to be trusted), but of being familiar with certain information or knowing how to produce the answers to questions that would be asked."

That instructional materials could be so important while so little attention is given to text selections seems contradictory. The CSSE report continued by pg:

"We did little to probe the procedures for changing and selecting course materials. (Superintendents responding to the national survey reported that in 70% of the districts the school boards did not get more than minimally involved in the review and selection of science curricular materials.) It seemed to teachers and administrators not an important topic. Some saw no leeway for changing, no money or no power. Most felt that materials were not among the "big" problems.

After all, instructional materials were budgetarily trivial. Far less than 2% of the average school district's budget was so spent. They were seen as dull stuff by most observers of education: who could create a poem, novel, or screenplay about the blossoming of a textbook?

But the recent EPIE survey revealed these monetarily trivial, topically dull things were crucial to science instructors in the U.S. Over 90% of the science teachers in a sample of about 12,000 teachers said their instructional materials were the heart of their teaching curriculum 90-95% of the time. Behind nearly every teacher-learner transaction reported in the CSSE study lay an instructional product waiting to play its dual role as medium and message. They commanded teacher's and learner's attention. In a way, they virtually dictated the curriculum. The curriculum did not venture beyond the boundaries set by the instructional materials." (CSSE 13: 65, 66).

If we accept these CSSE statements (and our groups found more evidence supporting than rebutting those conclusions), we come to a frightening conclusion. That is, that although texts virtually dictate the curriculum and therefore determine the emphasis of educational programs, major decision-makers (school boards) are only minimally involved in choosing them, and teachers and principals do not see text selection as an important task.

The Inquiry Group found "considerable evidence that many teachers and parents consider the primary goal to be preparation for the next level of schooling. There seemed to be general agreement that 'the next level', be it junior high, senior high or college would require preparation in knowledge rather than in inquiry skills" (Inq 9:9; CSSE 13:10).

The Biology Group found evidence of broad, general goals in rationales for science instruction and to some extent in textbook introductions. However, they found "in the classroom, narrow course objectives . . . were used as opposed to general goals. . . there is little evidence that the general, stated goals of science education are ever translated into curriculum or classroom practice. . ." (Bio 3:11). That group did, however, find evidence of small, but interesting enrollments in courses with goals oriented towards societal concerns for example, ecology, marine science and oceanography. The group went on to say "It is apparent, then, that the biology objectives are those of the biology textbook(s). Only 17 percent of the teachers feel a need for further assistance in establishing instructional objectives" (RTI B-115).

The Physical Science Group found "It is apparent that Goal Cluster III, fundamental knowledge, receives much more attention than the other three. . . with respect to personal needs. . . the emphasis is not great. The interface between science, technology and society is not given a very big priority. The academic preparation function. . . seems to restrict attention to societal needs. . . To some extent, the failure of school science to deal with societal issues must surely stem from the schools insularity; schools which make little attempt to involve members of the community in curriculum. . . or the development of educational goals are not likely to assign a high priority to the inclusion of societal issues in the science syllabus" (Phys 7: 16, 17).

Teaching Practices. Teaching practices were generally quite consistent with the apparent goals and perspectives described in the preceding section. There was evidence that most teachers "view science as a body of information to be learned as dogma and accepted on faith" (Bio 3:7). This view, combined with socialization goals discussed earlier appears to explain the normal sequence in science classes of "assign, read, recite, and test". There is very little utilization of out-of-school resources which would be especially helpful in pursuing societal and career-choice goals. Guest speakers and field trips, for example, are rarely used (RTI 103). Individualized instruction, a technique logically associated with individual needs, is not widely practiced (Phys 7:21; Bio 3:36). Laboratory exercises, when employed, appeared to be used to help convey the body of knowledge reflected in the textbook, and were not "explorations of genuine phenomena in settings in which outcomes are not known in advance" (Phys 7:20).

#### Student Outcomes

Student outcomes across the four goal clusters reflected the apparent curricular emphasis they receive. For example, our Physical Science Group summarized student outcomes across the four goal clusters by saying:

"It appears that the apparent lack of attention to Goal Clusters I, II and IV is reflected in the student outcomes as measured by the NAEP Science Assessment. For instance: (a) only about 20% 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" (Phys 7:18)..

The Biology Group found mixed, but similar results (Bio 3:47-54). The S/T/S Group found "a very low level of knowledge regarding S/T/S areas. For example, only 12% of 17-year-olds knew that plastics come from petroleum, only 3% were aware that the U.S. infant mortality rate is worse than that of most western European countries" (STS 12:21).

### Testing and Evaluation

One of the more difficult decisions at Phase II was the decision that time did not permit close inspection of classrooms and standardized tests. Thus, the information available was limited to consultants' familiarity with such tests, to rather brief treatments of testing in the data sources, to questions at the ends of chapters in textbooks, and to the in-depth study of all items used by NAEP in 1976. However, certain broad conclusions can be made with a reasonable degree of confidence. It is fairly clear that the primary purpose for testing in the classroom is to assign student grades which in turn serve as a primary incentive to the student to master the assigned content (CSSE 15:19). It also appears that tests influence teacher behavior in that teachers tend to teach those things which can be easily tested, i.e., facts and knowledge. As a result, the process outcomes, being difficult to test, receive little attention (Inq 9:14).

It also appears that most tests are no broader in coverage of the major goals and inquiry than is the curriculum itself. Thus, they are not amenable to use in broad decisions; and in fact, the case studies found the use of test results for instructional decision-making to be rare (CSSE 15:21-22).

The cycle III NAEP tests, used in 1976, "represent a marked improvement over previous tests (with respect to process), and may be an important catalyst for improving evaluation efforts in the inquiry domain" (Inq 9:15). For thirteen and seventeen-year-old students, the NAEP test also included at least sixty cognitive items tapping the interface between science, technology and society in areas including energy, environment, technological development, natural resources, and decision making, and a number of affective outcomes also pertinent to this area. However, NAEP coverage of the "societal" domain is still not nearly as good as its coverage of the traditional "academic" areas, and coverage of the personal and career choice areas is quite sparse.

### Inquiry

Our Inquiry Group considered the status of inquiry from a slightly different perspective than that used by the other focus groups. They considered the educational "contexts", "transactions" and "outcomes" associated with inquiry. Exerpts from the inquiry report exemplifying their findings are presented here.

"The widespread, espoused support of inquiry is more simulated than real in practice. Perhaps this discrepancy may be understood by analyzing the context, including a prospective teacher's education and professional training, where inquiry goals are articulated but the practice of inquiry receives negligible attention. The greatest set of barriers to the teacher support of inquiry seems to be its perceived difficulty. There is legitimate confusion over the meaning of inquiry in the classroom. There is concern over 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 web of barriers to teaching scientific inquiry becomes even more complex with a myriad of 'vicious cycles', nonlogical rationalizations, and social justifications. While these complications are identifiable, the important point is that a desirable context for inquiry instruction is lacking.

The transactions 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 they have on classroom practice. The following statements summarize the state of affairs related to the transaction of teaching scientific inquiry:

1. Not much time is spent on inquiry.
2. Little science is taught at the elementary level.
3. There are many pressures on teachers which compete for the time it takes to learn inquiry.
4. Even when hands-on experiences are provided to children, they are not characterized by problem solving.
5. Student disruption and classroom control work against inquiry development.
6. Teachers have not had many inquiry-type experiences themselves and appear to misunderstand it.
7. Inquiry learning is a difficult and high-cost operation.
8. Evaluation of inquiry outcomes is perceived as prohibitive compared to the more easily measured traditional outcomes.

In all cases of student outcomes, achievement increased with the age of the child, from 9-year-olds to 17-year-olds. The status of inquiry teaching in schools (Phase II Report, Section "Transaction") 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 community" (Inq 10:18, 19).

### Elementary Science

The Elementary Group reported a "not so encouraging picture" of science education in the elementary school. They found "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 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'" (Elem 11:4).

Despite the existence of good curricular materials, only 10-30 percent of teachers have heard of NSF developed curricula, and only one in three teachers have a district-designated person to support new techniques and materials.

There is pressure which mediates against effective science instruction at the elementary level. "The effect of the 'back-to-basics' emphasis is but one example of ways in which it exists. The teaching of elementary science is not so well established that it can exist independent of the influences of 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'" (Elem 11:5).

### Summary of the Status of Science Education

Essentially, we found science education to be pursuing rather narrow goals. The primary explicit goal was that of academic preparation for later coursework. Implicitly, students are prepared to be responsible, attentive and obedient workers. Little attention was given to goals related to personal use of science, preparing to make societal decisions regarding science and technology, learning about science-related careers, or the use of processes of scientific inquiry. Not only is this true for the college-prep courses of physics and chemistry but it is

also true for the students enrolled in "general" courses at grades seven through ten where 80 percent of all secondary science instruction occurs. At the elementary level, science appears to have a very low priority.

These problems appear to permeate many elements of science education, including the development, dissemination and adoption of materials, teacher preparation, teacher practice in the classroom, and student enrollments in various courses. The narrowness of goals pursued is reflected by student achievement on national assessment items which tends to be very low on items tapping knowledge of the science/technology/society interface.

The problems are difficult to overcome for a number of reasons. They include a general low priority for science education and with consequently, small expenditures for leadership at the local and state levels. The lack of leadership personnel results in little impetus for change, and little information flow about curriculum materials and teaching techniques.

### Phase III: Project Synthesis Recommendations

At the beginning of the project, we had certain plans for the Phase I report. It had been intended that during Phase II, a "profile of success" across major goals would be developed, and that at Phase III we would make interpretations and recommendations relevant to needs as related to each of these. The reader of recommendations would then be able to select those recommendations consistent with her or his philosophies regarding the broader purposes of science education. However, we had not anticipated the overwhelming preponderance of evidence that the whole system is driven by an apparent academic-preparation ethic, pays virtually no attention to learning outcomes associated with personal, societal or career-choice goals, largely neglects science education in the elementary schools and gives little attention to the processes of inquiry which lie at the heart of scientific endeavor. As a consequence of this unanticipated but unanimous conclusion we were no longer able to maintain a purely objective stance. Therefore, the bulk of the recommendations we have chosen to present deal with ways of increasing emphasis on achieving broader goals in pre-college science education. This choice is not made lightly. The changes recommended here are clearly at least as great in magnitude as those intended by the NSF-backed curriculum reforms of the 1960's. However, the danger that we may produce a generation of citizens unable to cope, either individually or collectively, with the increasingly powerful and complex influences of science and technology

on their lives is certainly as important a stimulus to change as were the dangers resulting in our "Sputnik fear" mentality of two decades ago.

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 a 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.

### Rethinking Goals

One over-arching recommendation applies to every person associated with science education, from the local to the national level. The recommendation 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 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. We are also confident that other persons who make an in-depth study of the status of science education will find precollege science education almost completely dedicated to the academic preparation goal, and will agree that major changes are critically needed.

### Needed Changes At The Local Level

Because curriculum decisions are made primarily at the local level

(here we use the term "local" very loosely to include building, district, multidistrict and state levels), the success of any course of action designed to produce major change ultimately rests on its effectiveness in impacting local practice by influencing local decisions. Because the changes recommended here may be antithetical to apparent basic assumptions and goal perceptions of most 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 rethinking processes at the local level. To the extent that goal orientations at the local level reflect a shift in emphasis toward personal and societal needs, there will be locally felt needs for new methods and materials. Therefore, a second requirement of any successful attack on the problem is that methods and materials be available as new needs are recognized locally. With these thoughts in mind, let us first consider what an "improved" situation would look like and then consider some strategies for moving in that direction. (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 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 "re-discovery" 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. 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.

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 a 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. Those 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 necessarily 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 students.

#### Strategies For Change

At all grade levels, changes can occur only as a result of local re-evaluation of priorities, evaluation of current program offerings and implementation of plans for change. This will probably require certain stimuli and resources which are now generally not available for making local curriculum decisions. Those needed stimuli and resources and consequent policy recommendation for national funding agencies are discussed below.

A Strong Leadership Function At The Local Level. Because the changes needed depend heavily on changes in basic assumptions implicitly embedded

in the entire science education system, persistent long-range efforts will be required. Such efforts are impossible without appropriate leadership at the local level. Characteristics required of effective local leadership include:

- (a) dedication to meet the needs of individuals and society, without sacrificing academic opportunities for that minority of students who plan to go on into scientific careers;
- (b) skill in implementing change processes at the local level;
- (c) a thorough knowledge of resources available for improving personal and societal aspects of science education.

Resources Needed For Local Change. There are a number of resources which are beyond the means of most districts to develop, but which are apparently needed in local change processes. They include:

- (a) Goal-setting models, specific to science education, which could guide locals through the important process of combining inputs from students, teachers, parents, administrators, researchers and others in determining the broad, long term goals for science education to be pursued by the local schools.
- (b) Methods by which broad goals could be translated into criteria for the evaluation of course offerings, curricular materials and classroom practices. This appears to be an extremely important component of any effective change process, as a close inspection of existing offerings, materials and practices reveals that they are largely inconsistent with typical broad goal statements. The "desired student outcomes", and other materials developed by our five focus groups during Phase I could be useful in this process.
- (c) Accurate information about the many curriculum materials currently available. Information would include source, cost, reading and mathematical difficulty, supplementary and laboratory materials needed, and emphasis on broad goals of science education, such as the four Synthesis Goal Clusters.
- (d) Step by step curriculum planning and development strategies resulting in long term plans leading to the fulfillment of goals set in (a) above. Strategies and techniques are needed for the following activities:
  - Evaluation and revision of course offerings according to criteria developed in (b) above.
  - Evaluating currently used textual material and practices, also using criteria developed in (b) above.

- . Identification and selection of materials and practices which better meet district criteria.
- . Development of supplementary materials to fill in where commercially produced materials are not available.
- . Development of materials and activities which utilize locally available resources--e.g., local examples of science phenomena; career opportunities exemplified by community scientists, engineers and technicians; local problems related to science and technology; and use of museums, factories, water treatment plants, factories and other facilities which show real-life applications of science and technology.
- . Implementation of new course offerings utilizing: public information campaigns; involvement of teachers in all phases of the change process; inservicing which stresses goal setting, new content, new techniques; revision of district testing and evaluation programs to reflect basic district goals; and use of school board and administration mandates to insure effective change.
- . Identification and effective utilization of persons outside the school who are willing to help improve science education through volunteer activities, community influence, etc.
- . Development of a case for science education in the school system and in the community at large by showing the value of science education in achieving goals valued by the community--e.g., cognitive development through "process science" in the elementary school, learning "how to think" by problem-solving and decision-making activities at the secondary level, etc.

#### Leadership and Coordination Efforts At A National Level To Meet

Local Needs. There are a number of possible activities at the national level which could greatly facilitate the development of the locally needed resources listed above. Obviously, it is a long and expensive list for even a national funding agency to fill. However, the alternative of expecting individual districts to independently develop the resources listed above appears even more expensive and quite unrealistic. Therefore, some strategies for developing such resources at the national level are imperative if change is likely to occur.

The development of such resources would require somewhat of a shift in priorities at the national level. Historically, NSF has provided resources for reasearch, curriculum development, laboratory materials and teacher training through colleges and universities. NIE has been interested

in dissemination and school change activities. However, neither agency has attempted to develop a comprehensive system for facilitating change in science education at the local level. What we are suggesting is that one of these agencies, or both acting in concert, broaden their sense of mission to provide such a comprehensive system. If NSF, for example, chose such a mission, its activities would no longer be limited to research, development and dissemination. Rather, it would shift to needs assessment (already begun) and subsequent coordination and facilitation of many efforts, both inside and outside of NSF, to meet identified needs. Its research, development and dissemination efforts would then be utilized to support that coordination and facilitation.

Some specific examples of activities and functions to be carried out in such an expanded mission include:

(a) Development of Model Systems For Change At The Local Level.

In the previous section, a number of resources which would facilitate change at the local level were identified. We recommend that model systems for change be developed at the national level. The systems should be detailed enough that a local agency could follow them with very little outside human assistance. The systems would be based on: emerging research in the fields of educational dissemination and educational change, examples of successful curriculum changes in science education and reports on the status of science education. Although the field of educational change is not sufficiently advanced to insure the development of viable systems, it is certainly advisable at this time to develop the best systems possible and to fund pilot attempts at their implementation in a variety of sites. Some research activities which would help refine such models are suggested later in the research section.

(b) Development of Information about Curriculum Materials. It was suggested earlier that one important resource needed by local agencies interested in specific changes in science education is information about available materials. Literally thousands of texts, laboratory guides, modules, tests, sourcebooks, etc. exist and are either available or reproducible for local use. For

any district interested in changing the thrust of its science curriculum, it is probable that somewhere there are materials they could use. Although various private and public agencies are active in evaluating and cataloging subsets of this domain there is no nationally coordinated effort to systematically search out, analyze and evaluate these materials with respect to their utility for achieving particular broad goals in specific situations. For example, if a suburban district decided to revise its junior high curriculum to deal more directly with societal issues, there is no place that district could find a good answer to the question "What are the available options in terms of texts to meet our purpose?". We recommend that such information resources be developed at the national level for two reasons: first, to provide sorely needed curriculum information to locals interested in change; second, to determine the most critical areas in which curriculum development is needed.

(c) Development Of An Information-Flow System For Science Education.

Evidence of little change in science education combined with lack of knowledge about innovative materials on the part of teachers, as well as emerging developments in the field of educational dissemination lead to the conclusion that there is an inadequate flow of information from research and development to practitioners. We recommend the development of information-flow systems which could serve as intermediaries between resources and potential users of those resources. Resources appropriately accessible through such a system would include the curriculum and educational change information suggested in a and b above, pertinent research information, the location of local systems working on similar problems, sites at which specific change processes or curricula are in operation, the names and credentials of consultants with specific skills needed in the change process, resource agencies at multi-district, state, regional and national level and the resources they provide, etc. Such an information-flow system would probably require operation at some intermediate level between nationals and locals. It might be developed cooperatively with existing agencies at the multidistrict, state or regional level. In any event, it should be readily accessible by phone to persons

working at the district or school level. Examples of agencies which now provide such services for education in general include the state dissemination capacity building projects which operate through state educational agencies.

(d) Development of "Learner Objectives Bank" And Test Items

Referenced to Major Educational Goals. As documented in an earlier section, there appears to be little direct relationship between broadly stated goals and specific learner outcomes. Thus, stated goals may change substantially with no apparent change in curriculum or learner outcomes. In our Phase I activities we were able to list personally and societally relevant learner objectives which served the purpose of "definition by example" for those general classes of learner outcomes. We recommend that similar efforts be undertaken on a much more comprehensive scale. The result would be a list of learner objectives (things worth knowing) referenced by rationales to broadly stated goals as well as to disciplinary topic areas. Inquiry skills appropriate to each broad goal as well as examples of activities appropriate to the development of such skills would also be included. Such objectives could serve two general purposes: as an evaluation tool, they could be used as a point of reference for evaluating curriculum materials either at the local or national level; as a development tool, they would provide a resource for selection of topics and learner objectives. Such a resource could be far more comprehensive than any which could be developed by an individual development project. It could be used by school districts, state agencies, federally funded developers and commercial text publishers. One reason such a development is so important is that most of us involved in science education are saturated with an academic "structure of discipline" perspective of science. The suggested development would provide us with points of reference and perspectives with which we are generally not fluent but which need to be reflected in the educational experience of most students.

With minor revision and editing, the working papers from Synthesis Phase I working papers could serve as a "stopgap" set of learner objectives for some purposes. Although inadequate

in scope to be used as the primary resource for new course development, it should provide adequate examples for the review of curricula and for local policy discussions regarding directions change should take.

Closely associated to the need for a comprehensive set of objectives which tap all four goal clusters and the various aspects of inquiry is the need for tests which reflect these areas. Because teachers tend to teach those things measured by tests, and because personal, societal, career choice and inquiry goals are largely not represented by existing tests, there is a need for such test items. We recommend that one of the resources to be made available include such test items in an easily identifiable and accessible form. Either NSF, NAEP or both working together should be able to collect and make available such items in some type of item bank, such as those being developed in other disciplines by the Northwest Regional Educational Laboratory in Portland, Oregon. We also strongly recommend that NAEP expand its coverage of these areas in any new future developments. The coverage of the academic areas of science already appears quite adequate.

e. Facilitation And Coordination Of Curriculum Development Efforts. If the above recommendations are successfully carried out, a significant shift in demand for educational materials should occur. It is essential that some means be found for meeting that demand. Any major efforts in development need to take several factors into account. They include:

1. Shifts in emphasis toward personally and societally oriented goals are likely to occur only gradually in practice.
2. Textbooks are likely to continue as the backbone of the school curriculum.
3. Various publishers appear to have a rather firm grip on the textbook market.
4. The magnitude of redevelopment needed may be extremely great.
5. Few districts have the resources to do a good job of developing their own materials.

Unless we assume major increases in the amount of federal money available for development, the factors listed above preclude reliance on federally supported curriculum development to meet all needs for new curricula. A more efficient use of limited resources would place federally funded agencies in a role which stresses leadership, facilitation and coordination of many forces and resources involved in curriculum development. As one considers various alternatives in that direction, it is useful to keep in mind the alternatives available to a local system which desires to broaden its goals to include more topics of personal and societal relevance. Alternatives include:

1. Develop its own materials.
2. Develop supplementary activities and materials to complement existing materials.
3. Seek existing materials which meet the new criteria.

The "objectives bank" idea, suggested earlier, would serve as an invaluable resource for a district in developing its own materials or in supplementing existing materials. It could also enable textbook publishers to react more quickly to perceived changes in the marketplace. Likewise, a comprehensive change model and persons trained to facilitate educational change, both suggested earlier, could facilitate local development activities.

All recommendations made thusfar could result in considerable duplication in the field of curriculum development unless they are accompanied by a large scale information flow system. We therefore recommend that an "effort coordination function" be developed at the national level. Some activities contained in this function would include:

1. Identification and evaluation of existing materials with reference to major goals as discussed in detail earlier.
2. Maintenance of current information about local curriculum development projects in action.
3. Coordination of the many "limited focus" projects the goals of which are consistent with those of personal and societal needs. A few examples of agendas which fall into this category are: environmental education, career education,

energy education, marine education, conservation education, safety education, etc.

4. Coordination with professional organizations in the development of special publications, newsletters, etc.
5. Development of the capacity to package and deliver resource information appropriate to the needs of local systems as detailed above.
6. Facilitating of communication and cooperation between local systems with common goals and needs.

The activities described above should permit a federal agency to aid local systems regardless of the change alternatives they choose. Thus, it could facilitate change without being vulnerable to the charge that the agency was promoting specific materials which are philosophically unacceptable to certain special interest groups.

So far, we have suggested mainly market forces (i.e., change in demand) as influences on text authors and publishers. However, more direct influences should be explored. At the very least, attempts should be made to open lines of communication with publishers and established authors, to discuss the issues identified in this report and other similar reports, and to seek ways of achieving some of the changes recommended here.

One possibility for stimulating incremental change in existing texts would be a national demonstration project in which the revision and marketing of a popularly used text would be supported by a national funding agency. The purpose of the revision would be to add ~~personal~~, societal and career emphasis as quickly as possible to an existing text. The result would be a "transitional text". Although such texts would not meet all the criteria suggested in Phase I, they would have the advantage of quick entry into the text market. Such a demonstration project could serve a number of purposes. First, it would answer questions regarding:

1. The feasibility of such revision
2. The cost of such revision
3. Market acceptance of texts revised to address new goals
4. Feasibility of federal agencies and private publishers working cooperatively in this respect

f. Direct Curriculum Development. If increased funds are made available by legislative action (and we strongly support major increases), large scale curriculum development activities should be funded at the national level. We recommend that the place to start such development is at the middle school and junior high school levels for the following reasons:

1. Science education at this level is not so strongly based on assumptions regarding academic preparation. Therefore, changes at this level may come more easily than at the high school level.
2. Most of our students' exposure to science occurs at this level, especially for the general student population; therefore, a limited number of programs could conceivably reach many students.
3. The development of "transitional texts" as described in the previous section appears less promising at this level than at the senior high level.

Obviously such developments should be based on research and development efforts regarding the most useful knowledge and skills for personal, societal and career decisions. Although reading difficulty was outside the scope of our study, we were often struck by the reading difficulty and abstract nature of currently used junior high curricula. We urge that any new development activities utilize the expanding knowledge base regarding cognitive development to a much greater extent than have previous efforts.

g. Needed Research. There are a number of areas in which research information would be very useful in facilitating improvement in curriculum and instruction. Some which seem especially important are discussed here.

1. More research in the curriculum decision-making processes which occur at the local level is needed. From the data base we inspected, some generalizations about these processes could be formed. However, much more needs to be known before comprehensive systems for facilitation of this critical activity can be developed. Information is needed on the roles typically played by principals, teachers, text salesmen, etc. Also, more information is required about the criteria for appointment of teachers to curriculum committees, and the criteria they use in the selection of texts.

2. Research is also needed to determine effective ways for local systems to achieve changes in science education. Case studies of locals which have succeeded in selecting innovative materials and implementing those materials, as well as those which have succeeded in modifying science teacher behavior would be very useful. The CSSE case studies were designed to randomly sample representative districts. Their sample did not include districts which had exemplary science programs, as measured by the criteria developed in our Phase I reports. To the extent that such districts exist, they should be identified and elements of their change efforts which led to success should be analyzed and disseminated through whatever information-flow systems are developed. Associated with the case studies would be research into "barriers" in science education (see Elementary and Inquiry Reports). Essentially, it should be determined which barriers are real and which are imagined. Research into ways of overcoming those barriers is also needed. Research is also needed to determine effective methods of producing changes in educational practice consistent with specific curriculum decisions. Although there is a considerable research endeavor in general educational change processes, there is not a sufficient research base to guide local activities designed to produce the specific changes in teacher behavior required for implementation of new science curricula.
3. Collection and/or consolidation of research information which can help "make a case" for science education in general, and for a broadening of goals in particular would be quite useful to science education departments attempting to influence local administrators and school boards to allocate resources to improve science education. Useful information in this category includes: the effect of "process" science teaching on cognitive development, especially at the elementary and middle school levels; the effect of relating science principles to societal issues and of practice in decision making on student outcomes as measured by instruments assessing science-society-interface topics (for example, NAEP items in that area); the effect of instruction on science-related career choices of students; student attitudes regarding science courses stressing personal, societal and career-choice goals, as compared to attitudes regarding academic courses; the effect of various kinds of science instruction on students' "real world" behaviors;

4. Normative and theoretical research on goals and objectives for science education would be especially useful at this time. As the domain of science information continues to expand, the judicious selection of subsets of that domain for public education becomes increasingly crucial and increasingly difficult. Future oriented research on the knowledge most likely to be needed by the general population in the next few decades, would be especially useful to those who choose curriculum on criteria related to the utility of knowledge represented by the curricular materials.

None of the changes recommended here can occur without policy endorsement both at the local and national levels. Ultimately, policy is set by political constituencies. Because the goal clusters used in this project came from broad statements of educational goals from sources including a number of political constituencies, there is a reason to believe they are supported by many persons involved in educational policy. However, the extent of that support and its exact nature remain largely unknown. We recommend that efforts be extended at the national level to assess the relative importance placed on major goals (such as those identified by our project) by various educational decision makers including:

- parents
- teachers
- students
- the general population
- school boards
- college professors of both natural science and non-science disciplines (for whom many teachers are preparing students)
- working scientists
- paid educational employees in leadership roles
- legislators

We further recommend the development of local processes for determining goal perceptions of various local groups and incorporating those goals into curriculum-decision processes. These processes could utilize some of the methodology developed in the national study recommended above. We are convinced that the data collected will provide a strong influence for change among educational policy makers. Such influence will be indispensable if change programs are to succeed.

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CHAPTER 2

PHASE I BIOLOGY REPORT:  
THE DESIRED BIOLOGY PROGRAM

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### Rationale

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. The primary sources of information are listed in the bibliography.

The justification for seeking a new rationale for the teaching of biology results 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 in method and substance with technology. Science and technology have become the two faces of a single "coin". Advances in the biological sciences are the result of (1) new theoretical insights (sociobiology); (2) new technologies for research (recombinant DNA); (3) new interdisciplinary perspectives (biophysics, biochemistry, environmental psychology, human ecology); (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, future developments and survival are under control of the human species itself; and, (6) new insights into biology as the link between the natural

laws, future developments and survival are under control of the human species itself; and, (6) new insights into biology as the link between the natural and social sciences giving rise to new cross-disciplinary perspectives (social biology, human geography, ecological psychology) and an effort to comprehend human life as a whole.

The over-arching mood of the desired biology program is to use the knowledge of the biological sciences 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 directed toward an increasing capacity for human adaptation. Biology taught for these purposes involves questions of ethics, values, morals, and aesthetics as well as scientific considerations.

The design of a biology curriculum oriented to human understanding, human welfare, and social progress has dimensions in the personal needs of individuals, their career aspirations, and the social milieu. The criteria for the selection of salient knowledge to form the curriculum framework arises from human beings and their interactions rather than from the structure of biological disciplines. What such a curriculum might be like with these characteristics is presented in the following sections of this report.

Exemplars of Salient Biological KnowledgeGoal Cluster I - Personal NeedsGenetics.

1. Appreciates the role of genetic counseling in making decisions about marriage and family affairs.
2. 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.
3. Understands the concept of the gene pool and its role in human evolution, including the effects of man's intervention (medical and other advances) on the gene pool.

Evolution.

1. Recognizes that human beings have a long history on this earth and during this period of time have undergone a continuous process of change and development both biologically and culturally.
2. Appreciates that changing biological and cultural factors influence our life patterns today and will continue to do so.
3. Understands cultural evolution as a corollary to biological evolution.
4. Understands the role of personal beliefs, attitudes, and values as a result of human evolution and as they influence cultural evolution.

Nutrition.

1. Is able to choose a diet that will maintain optimal health and efficiency.
2. Knows the positive and negative effects of personal diets (for both long and short term diets).
3. Knows the long-range effects of poor diets (anaerxia, pre-natal nutrition, aging, hyperactivity and mental ability) and recognizes the necessary changes to improve the diet.

Behavior.

1. 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.

2. Recognizes that behavioral patterns in individuals are not constant but are influenced by social and biological development, chemical imbalances, nutrition, cultural values, peers, and personal experience.
3. Understands that human behavior is the means by which people adapt to conditions of life and living and that motivation and learning are essential conditions.
4. Understands there are both positive and negative consequences of behavior.
5. Recognizes and accepts that personal behavior patterns are determined by the mores of the social group.

#### Continuity.

1. Understands that the continuity of human life on earth is maintained through a process of reproduction.
2. Appreciates the uniqueness of human sexuality compared with that of other organisms.
3. Recognizes that the normal process of human reproduction can be influenced by disease (VD), genetic factors, birth control techniques, and personal preferences.
4. Understands the effects of mutagenic agents on the processes and factors of continuity.

#### Structure -- Function.

1. Appreciates that the well-being of a human being is dependent upon a proper functioning of the various organs and tissues of the body.
2. Understands that the improper functioning of one bodily system is likely to influence the normal functioning of the other systems.
3. 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.
4. Knows that some processes are necessary for continual personal development (maintenance with change or growth).

#### Diversity.

1. Appreciates that all human beings are unique in the sum of their characteristics - biological, social, psychological, experience, responsiveness, etc.

2. Recognizes that the behavior of the human species is unique in comparison to other organisms.

#### Integration.

1. Knows and can interpret the factors and conditions which influence the coordination of bodily growth, development, and functioning.
2. Recognizes the extent to which the effectiveness of bodily integration can be influenced by personal efforts, such as, proper nutrition, exercise, training, mental health, etc.
3. Understands the prenatal influence on sexuality, personal growth and development.
4. Understands the importance of integrating the various aspects (cognitive, affective, motor, and social) of personal development.

#### Life Cycle.

1. Understands and appreciates the human life cycle as it is influenced by biological, cultural, and psychological factors at different phases extending from birth to death (birth, childhood, early adolescence, adolescence, maturity, aging, death).
2. The human life cycle can be influenced in its course of development by prenatal conditions, nutrition, environmental conditions, disease, response to social, biological, and environmental stress, etc.
3. Appreciates the unique and special aspects (both positive and negative) of the various life stages.

#### Energetics.

1. Appreciates that human efficiency and survival depend upon maintaining an adequate internal and external energy exchange system.
2. 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.
3. Understands that one's normal metabolism can be negatively influenced by such factors as drugs, poor nutrition, environmental conditions, etc.

### Goal Cluster II - Societal Issues

#### Genetics.

1. Knows that genetic principles can be applied to improving plants and animals.

2. Recognizes that various chemicals in the environment (pesticides, herbicides, preservatives) may affect the food web, change the evolving gene pools and reduce the overall effectiveness of natural selection.
3. Accepts a personal responsibility for using genetic information in advancing human welfare; practices bioethical tenets.
4. Recognizes the need for societal understanding of genetic issues and the danger inherent in misunderstanding.

#### Evolution.

1. Is aware that human beings have some control over their own evolution through differential artificial selection, cultural practices and environmental controls.
2. Recognizes that efforts to control human evolution may have negative as well as positive implications.
3. Is aware of differing points of view about the desirability of efforts to control human evolution and the direction it should take.
4. Knows the various processes of social-cultural evolution.
5. Appreciates the unique contributions of humans to the evolutionary process.

#### Nutrition.

1. Recognizes that malnutrition is widespread in all countries and is not limited to impoverished peoples.
2. Knows about and supports research for the improvement of food products and nutrition.
3. Recognizes that adequate nutrition is both a personal and social responsibility.
4. Recognizes the role of advertising and other societal constructs in influencing food choices.
5. Is aware of social patterns which influence nutritional deprivation.

#### Behavior.

1. Understands and is aware of ways in which human behavior is influenced by the social, cultural and natural environments.
2. Is aware of ways in which human behavior is influenced by group pressures (political, peer, religious, economic, territoriality).

3. Understands the interaction of cultural and personal values in determining human behavior.
4. Knows the conditions and effects of chemicals (drugs, alcohol, tranquilizers, nutrition) used to modify human behavior and the need for social controls.
5. Understands both the necessity and the limitations of societal control of drugs and chemicals (Pure Food and Drug, FDA, etc.); and the effects of strong lobbies on these laws.

#### Continuity.

1. Recognizes that human population growth can seriously influence the quality of life in various ways (economic, social, food, energy, etc.).
2. Is aware that cultural mores and personal and religious values influence patterns of human sexuality and attitudes toward offspring.
3. Appreciates the responsibility human beings have for the preservation of all species of living organisms.

#### Structure -- Function.

1. Appreciates the interaction of human populations and cultural systems and senses a responsibility for maintaining the health of these systems (communication, education, transportation, health services, natural environment, etc.)

#### Diversity.

1. Recognizes and appreciates the uniqueness of different cultures and social systems as well as variations in human populations.
2. Accepts the notion of diversity as essential to human survival and cultural richness.
3. Recognizes the need and the responsibility to retain in a "pure" state unique cultures and social systems.

#### Integration.

1. Recognizes and understands the extent to which there is need for social control (government) of products and circumstances likely to influence the normal biological condition and responses of human beings.
2. Seeks to formulate a personal value system about the extent to which controls over human responses should be socially managed.
3. Recognizes the need for societal intervention into human behavior patterns which are negative (battered wife, child, etc.).

Life Cycle.

1. Recognizes the need to keep informed of changes, population patterns in the human life cycle, such as, birth rates, distribution of age groups, family structures, etc.
2. Understands how achievements in science, especially biology, may influence the life cycle of human beings.
3. Recognizes ways in which environmental factors may contribute to modifications in the life cycle of human beings, including death of the species.

Energetics.

1. Understands that human beings are a vital link in the web of life that sustains living forms on the earth.
2. Identifies and evaluated ways in which human beings may influence the energy cycle through changing the biomass (green revolution, hybridization of improved nitrogen fixing plant species, etc.).
3. Appreciates the possible effects of human population distribution on the energy cycle.
4. Recognizes the negative impact of human societies on many natural energetic systems and formulates constructive changes.

Goal Cluster III - Salient KnowledgeGenetics.

1. Knows the basic laws and facts of genetics and their relation to reproduction and the continuity of species.
2. Knows the extent to which patterns of heredity may be modified by mutations, natural or induced.
3. Knows some factors which may increase mutations.
4. Understands probability, chance, and prediction and the way these factors affect human (and other) genetics.

Evolution.

1. Understands that all species of organisms, including human, tend to manifest changes in structure and function over time.
2. Knows that species differ in their adaptive capacity but all are subject to environmental conditions.
3. Knows that human beings have developed ways of manipulating the natural environment which can influence the adaptive capacity of organisms including human.

Nutrition.

1. Knows the classes of foods (fats, proteins, carbohydrates) and their biological functions in maintaining growth, energy and health requirements.
2. Knows supplemental food requirements (vitamins, minerals, water), their functions and natural sources.
3. Knows the fundamentals of maintaining a diet for optimal health.
4. Knows the consequences of not maintaining a proper diet.

Behavior.

1. Knows that the capacity for human behavior is determined by an interacting combination of factors including heredity, environment, experience (learning), physiological (hormones) and psychological (responsiveness), and cultural values/patterns (mores).
2. Knows that behavioral patterns are distinctive within species and between species (individual and group patterns), but that there are commonalities within species.
3. Recognizes ways in which the behavioral responses of human beings are influenced by the social milieu, cultural norms, physical environment (crowding, safety, etc.), and personal awareness (self-concept, social hierarchies, peer pressures, etc.).

Continuity.

1. Understands the processes of reproduction, sexual and asexual.
2. Knows that genetic patterns are modified in sexual reproduction.
3. Can interpret the meaning of sexual reproduction in terms of the evolution of the species.

Structure -- Function.

1. Knows the structural - functional relations in the organizational levels of organisms (molecular, cellular, tissue, organ, individual, population, world biome).
2. Knows the life support systems of multicellular organisms (plant and animal), especially those of human beings, including the excretory, digestive, nervous, integumentary, circulatory, respiratory, reproductive, regulatory, and supportive.
3. Understands that the life support systems of animals is ultimately dependent upon photosynthesis in plants.

Diversity.

1. Appreciates the significance of diversity in the survival of living things.
2. Understands the interactive factors of organism diversity and the natural environment (including the social environment in humankind.)
3. Recognizes the advantages of a classification system in describing and identifying diverse organisms.
4. Recognizes that homeostasis and regulation are central to the concept of function.

Integration.

1. Understands the importance of unifying and regulatory systems in multicellular organisms.
2. Knows the integrative mechanisms in human beings, such as, (a) chemical controls - hormones, minerals, vitamins, enzymes; (b) nervous system - neurons, learning, training, and, (c) circulatory system - respiration, homeostasis.

Life Cycles.

1. Knows patterns of development among plants and animals.
2. Understands the uniqueness of human development and its significance.
3. Recognizes that there are typical and atypical processes of growth and development and their relationship to biological, psychological, and societal influences.
4. Understands the human life cycle from prenatal (conception) to death.

Energetics.

1. 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

Career education as an educational concept and priority from the elementary school through college was brought into focus in 1972 by a series of congressional acts. In 1978, a congressional bill titled the National Career Education Incentive Act was signed into law. This Act specified funds

to implement career education in every school district throughout the nation. The thrust of career education is to help students understand the close relationship between education and work, to help them become aware of a variety of careers, and to provide opportunities for them to test their interests.

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 endeavors 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, technicians, laboratory assistants, translators, computer programmers, equipment designers, and many more. Then, there are careers for people that make use of biological knowledge, for example, 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.

Teachers in the biological sciences should provide students with opportunities to meet and talk with people in biological vocations; to do library research on careers; to discuss career characteristics with informed teachers or counselors; to "shadow" people employed in biological vocations; to gain work experience (paid or unpaid) whenever possible; to participate in field trips where people are employed in biological endeavors. Films, bulletin boards, career pamphlets and other materials should be continuously available to stimulate student interest in careers.

Learning about careers in biology should be a continuing theme throughout a course rather than dealing with careers as a single effort in a special unit or module of classwork.

The biology focus group views the development of career awareness as a major goal of biology teaching and as an essential element of instruction. A biology course designed for the advancement of human well-being ought not neglect one of the central features of human living - that of work.

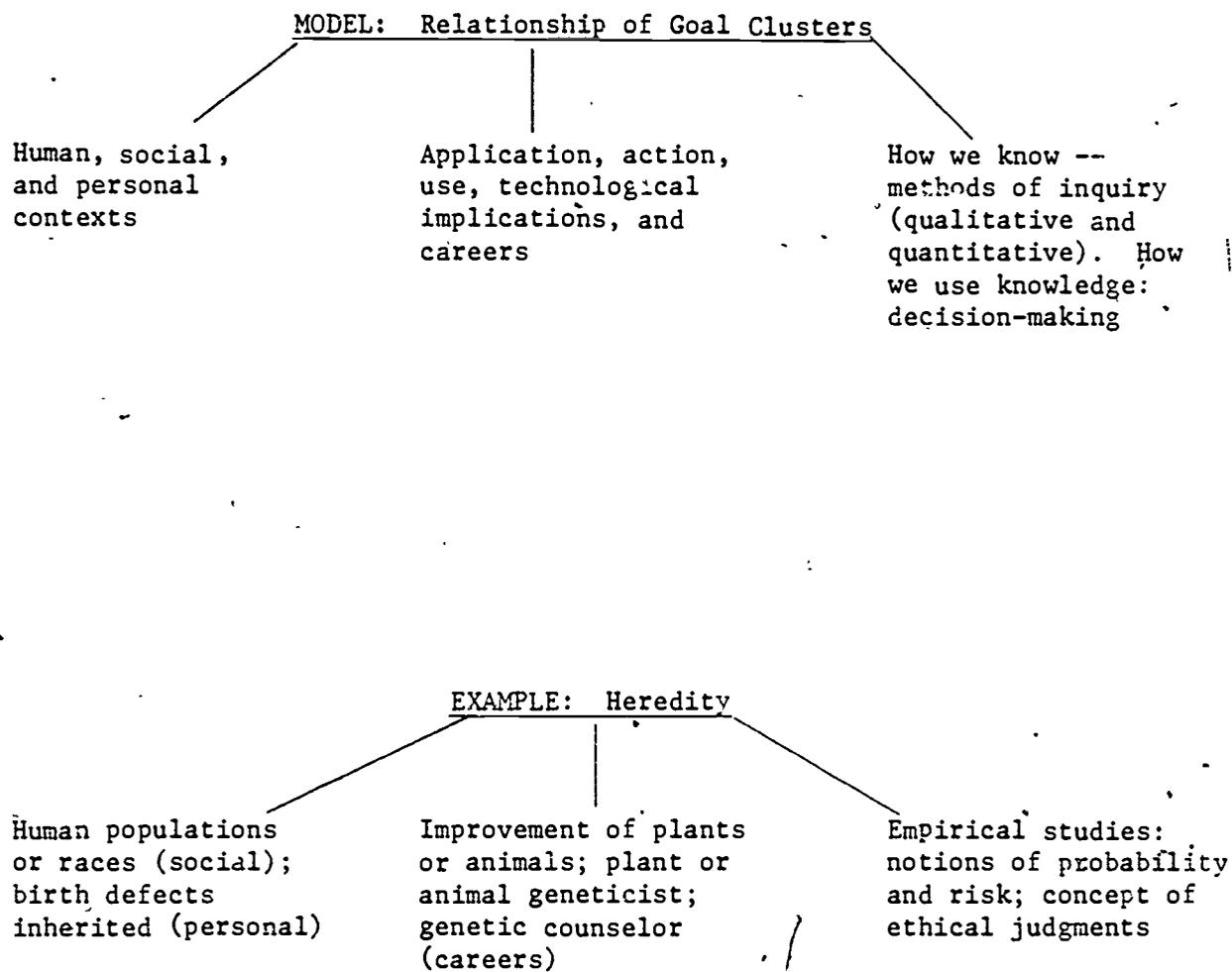


FIGURE 1: A DESIRED STATE OF BIOLOGY TEACHING - THE CURRICULUM ORGANIZATION

Information Processing in the Desired Biology Program

When a biology program is placed in the context of personal, societal, and career goals, how knowledge is managed also changes. How inquiring systems are designed and how information is processed take on new dimensions.

The classical concept of scientific inquiry - problem identification, information gathering, hypothesis, experiment, verification - is inappropriate or limited for resolving bio-personal and bio-social problems. The very fact that variables in problems related to human life and living can seldom all be identified, and even less frequently controlled (measured), limits the appropriateness of the so-called "scientific method".

The teaching of biology in personal and social contexts is primarily for the purpose of making knowledge useful in the human endeavor and in the real world of the student. Thus, there is an emphasis on how knowledge is used, as well as on how knowledge is acquired. The art of and formal processes of using knowledge have distinctive characteristics that separate them from ways in which information is acquired by investigative means.

The Project Synthesis inquiry group in their report is considering the special characteristics of scientific inquiry (information discovery) and of decision-making (information using). At this point the biology focus group will only identify some of the major elements essential to teaching biology in the context of personal, social and career goals. These elements are:

Bio-feedback: in natural systems

Probability: in a statistical sense

Uncertainty: in contrast to probability where possible outcomes are known

Risk: as a situation in which probabilities can be assigned to possible outcomes of an action

Curvilinear relationships: diminishing returns, thresholds

Exponential growth: geometric growth

Interactions: ecological sense

Systems concepts: relationship of subsystems

Classification systems: advantages

Holistic: viewing of problems

Reductive: viewing of problems

Decision-making: as a satisfactory solution to a problem and an optimization

Multicausality and multidimensionality: of biological problems (multifactorial)

Systemic thinking: in contrast to linear thinking

Decision-making: in value, ethical, and moral contexts (perceptual frames)

Limitations of scientific inquiry: for problems imbedded in personal and societal contexts

Problem centering: in contrast to methodological approaches

Qualitative investigation: case studies, anthropological methods

Sampling techniques: individual, selected and broad populations

Longitudinal studies: growth or change over time

Tolerance for ambiguity

Problem resolution: in contrast to problem solving

Futures methods and thinking: goal-setting, modeling, extrapolation, projecting trends, intuiting, metaphor, simulations, scenarios, forecast

The attributes listed above are illustrative of the information management and processing skills (including attitudes) that become important in the teaching of biology when educational goals are student-directed rather than being limited to those characteristics of the discipline.

## Critical Elements and the Desired Biology Program

### Objectives and Student Outcomes

The objectives of the desired biology program focus on the study of the human species as a part of nature (1) to understand humankind as a distinctive organism; (2) to appreciate the universal human need to be in touch with nature, our own nature, and all of nature; and (3) to learn to live in harmony with nature and to minimize the dissonance between human beings and 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 salient biological knowledge for achieving these objectives is described in a previous section under the four goal clusters of Project Synthesis.

### Program Existence

The desired biology program already exists in part in those schools providing courses or special modules on such topics as: (1) environmental studies; (2) human physiology; (3) health - particularly those aspects dealing with alcohol, drugs, tobacco; (4) disease; and, (5) futures.

### 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 desired course. Some of these textbooks are:

1. Robert McNally, Biology: An Uncommon Introduction; 1974, Canfield Press, S. F.
2. Donald J. Farish, Biology: The Human Perspective; 1978, Harper and Row, N.Y.
3. S. Singer and H. Hilgard, The Biology of People; 1978, Harper and Row, N.Y.
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6. G. Hardin and Carl Bajema, (3rd Ed.), Biology: Its Principles and Implications; 1978, W. H. Freeman and Co., S. F.

Some 300 colleges and universities now have courses or majors in human biology in which the personal and social implications of biology are considered. These programs could be made available to teachers through summer institutes, seminars, or as an inservice program.

The difficulty of dissemination is minimized by the fact that new and salient concepts of biology will not need to be acquired by a qualified biology teacher. The change in subject matter is in the context in which it is taught - a shift from a discipline focus to one that is taught - a shift from a discipline focus to one that centers upon the student as a biological organism living in a cultural and social environment.

#### Program Implementation

The desired biology program 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 characteristics 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:

##### Personal Needs.

1. Seeks and tolerates conflicting points of view when based upon knowledge and encourages discussion.
2. Is effective in interpersonal relations facilitating discussion.

3. Does not force closure - introduces new information, raises new question, "appropriately" expresses own opinions.
4. Knows how to deal with individual and group activities in a variety of situations.
5. Respects and cares for adolescents and relates biological knowledge to individual problems.

#### Societal Issues.

1. Uses group dynamics in the classroom as an application of larger social issues.
2. Uses processes of group problem solving, decision making, and conflict resolution.
3. Is aware of his or her and the student's place and role in the classroom, community, society, and world.
4. Knows the major biosocial problems and relate biological knowledge to their resolution.

#### Salient Knowledge.

1. Knows the concepts and principles of biology as they relate to personal needs and social issues.
2. Has a knowledge of the basic concepts in those cognate fields (anthropology, psychology, sociology, economics, human geography, political science, future studies) that are relevant to the personal-social-career goals of human biology.
3. Recognizes that curriculum and professional development are life-long processes for teaching an up-to-date, action-oriented, personal-social biology.

#### Career Knowledge/Awareness.

1. Knows sources of information on biology related careers.
2. Has contacts with practicing biologists in various work fields.
3. Knows and makes use of community resources for developing career awareness in students.

#### Classroom Practices

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

1. A Problem Approach to Curriculum Organization and Teaching - These procedures are described in the Project Synthesis Inquiry Group Report and in the inquiry supplement reported in a previous section of this report.

2. Individualization - The goal cluster, personal needs, requires individualized instruction at appropriate places in the curriculum.
3. ~~Cooperative Activities~~ - The societal issues goal requires members of the class to work cooperatively in the resolution of problems and issues.
4. "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 ethics, value or moral context and lead to decisions 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 social 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.

Bibliography: The Sources of Goals for the Teaching of Biology

The publications cited here represent, in part, the normative data base for identifying the "desired" goals for the teaching of pre-college biology.

The dialogue about the need for reform in secondary education as a whole and in the teaching of science and biology in particular is reflected in the following representative publications. Each of the publications is either a symposium volume or the report of a committee, providing on one hand a wide perspective of opinions and on the other a consensus. Curriculum movements in biology arise from a diversity of social pressures and school dysfunctions along with new insights and shifting emphases within biological disciplines. There are also other factors which contribute to the ferment which signals that the time has arrived for a new curriculum to emerge.

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CHAPTER 3

PHASE II BIOLOGY REPORT:  
THE ACTUAL BIOLOGY PROGRAM

Biology Focus Group Members:

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## PHASE II BIOLOGY REPORT: THE ACTUAL BIOLOGY PROGRAM

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A  
PHASE II BIOLOGY REPORT: THE ACTUAL BIOLOGY PROGRAMIntroduction

The Phase I Biology Report of Project Synthesis describes an idealized biology curriculum reflecting: 1) current developments in the biological sciences; 2) bio-social issues in contemporary society; 3) indicators of present and future personal needs for an understanding of biology; and 4) the contemporary nature of science as a social process. The Phase II Biology Report is a study of the actual conditions and practices of biology teaching in the American schools as they existed in 1977. The Phase III Biology Report goes on to discuss implications of discrepancies between "ideal" and "actual" states.

The organization of the Phase II report is consistent with that of the Phase I report. These reports describe ideal and actual precollege biology teaching in terms of four broad goals related to: 1) personal needs; 2) societal problems; 3) scientific knowledge; and 4) career awareness and education. Essential to the attainment of these goals are a number of critical elements important to sustaining the curriculum and teaching practices. Such elements include laboratory facilities and equipment, time to teach, qualified teachers and other factors. Critical elements such as facilities, teacher qualifications and extent of student exposure to biology instruction are examined in terms of the stated goals and objectives for the teaching of biology described in the Phase I Biology Report. In addition to the four broad goals mentioned above, the actual state of biology instruction will be described from a fifth perspective - inquiry.

The data for describing the actual state of biology teaching in the United States were obtained primarily from the following sources: "The 1977 National Survey of Science, Mathematics and Social Studies Education" conducted by the Research Triangle Institute (RTI), "The Status of Pre-College Science, Mathematics, and Social Science Education: 1955-1975," a literature review prepared by the Center for Science and Mathematics Education at the Ohio State University (OSU), "Case Studies in Science Education" conducted by the Center for Instructional Research and Curriculum Evaluation at the University of Illinois at Urbana-Champaign (CSSE), and the "Third National Assessment of Science" conducted by the National Assessment of Educational Progress (NAEP). Additional data were obtained from the BSCS Biology Teachers' Handbook, third

edition, and "A Survey of Science Teaching in Public Schools of the United States Volume 1, Secondary Schools" (ERIC/SMEAC).

Additional information on the status of biology teaching was obtained from an analysis of commonly used textbooks in junior high school science and in high school biology teaching. These books are cited in the sections of this document in which they are described.

The Phase III Biology Report discusses discrepancies between the desired and actual biology programs, identifies information gaps, makes suggestions for needed research and recommends possible solutions to problems and issues of biological education.

#### Major Goals

The discussion of the actual state of goals in biology teaching will focus on the following areas: inquiry, personal needs, societal problems, scientific knowledge and career knowledge.

#### The Inquiry Goal

It appears that science teachers give little effort to realizing the inquiry goal (CSSE 12:3 and 7). For example, the BSCS laboratory guides (CSSE 12:5) are likely to be stored and not used (BSCS 60). Also, teachers do not use questioning techniques or other instructional procedures that facilitate systematic inquiry (CSSE 12:4). Although 50% of the biology teachers have attended NSF institutes (CSSE 12:7), they do not feel confident in teaching biology by inquiry processes (CSSE 12:3). A variety of instructional resources for teaching inquiry have been developed, such as laboratory "blocks," "invitations to inquiry," student research problems and inquiry films and slides, all in addition to the laboratory exercises accompanying the BSCS textbooks (BSCS 60). Investigations designed to indicate the effectiveness of inquiry materials for teaching biological inquiry have produced conflicting results (BSCS 55-57). There is little positive evidence that students in biology attain an understanding of scientific inquiry as a process, that they develop relevant inquiry skills, or that they can use these skills to think critically about science-related problems.

There are a number of factors preventing widespread success in attaining the inquiry goal. First, teachers are not "model inquirers" for their students (CSSE 12:2), nor have they been educated in methodologies of biological research (CSSE 12:7). Second, biology teachers lecture more than 75% of class-time (BSCS 56); thus, students have few opportunities to initiate questions

(CSSE 12:5; BSCS 56). Third, inquiry as a goal of science teaching is generally not seen as productive and is, therefore, not accepted by biology teachers (BSCS 56; CSSE 12:7). Fourth, teachers who are aware of inquiry as a goal of biology teaching often feel that only bright, highly motivated students can profit from inquiry teaching (CSSE 12:7). Typically, two-thirds of tenth grade biology students are at the concrete level of intellectual development (BSCS 62) which undoubtedly limits their ability to comprehend the attributes and processes of scientific investigation. Students taught inquiry skills are no better than students not taught such skills at applying these skills to novel problems (BSCS 60). Fifth, inquiry teaching is seen by teachers as time consuming, reducing the time needed to teach "the basics" (CSSE 12:5). "Basics" is interpreted as the learning of facts and getting "right answers" (CSSE 12:10).

Research biologists, learning psychologists, and science educators associated with the curriculum reform movement of the 1960's advocated teaching biology as a process of inquiry. Curriculum materials, classroom and laboratory were designed to engage students actively in procedures biologists use to establish reliable information. However, this goal was not generally acceptable to teachers who are more inclined to view science as a body of information to be learned as dogma (CSSE 12:9) and accepted on faith (CSSE 12:10).

#### The Personal Needs Goal

There is considerable rhetoric by administrators, teachers and parents about meeting the personal needs of students through science education. This rhetoric takes the form of "life and work skills related to science" (OSU 172), the "preparation ethic" (CSSE 12:16) and vocational or career education (OSU 147). Science courses profess to emphasize "things that will be useful in everyday living" (CSSE 12:45). It appears, however, that the goal of fulfilling personal needs is not realized in practice for two reasons: (1) young people not knowing what they need (CSSE 12:45) and (2) the increasing emphasis on the "basics" (CSSE 12:16).

There are attempts being made to meet personal needs through advanced placement courses or courses on such topics as health. For example, a socially relevant course on environmental education provides fundamental knowledge that stimulates students to "examine the life worth living" (CSSE 12:43).

The goals of personal needs as identified in the Phase I Biology Focus Report have always been subordinate in science programs, especially when compared

to "basic" knowledge goals related to scientific knowledge. In the past ten years, the goals of personal needs have increased in importance. These goals are closely related to the goals pertaining to societal problems and career knowledge.

### The Societal Needs Goal

Science teachers and "state level personnel" have shown an increasing interest in societal goals (OSU 172 and 175; CSSE 12:43) and in objectives to make science relevant to the concerns of all students, not just to those who are academically talented or college-bound (CSSE 12:41).

The goals for teaching secondary science are in transition; there is increased emphasis on environmental concepts, societal concerns and world problems, decision-making and interdisciplinary studies (OSU 21). There is evidence also that state departments of education are influencing these changes through their legislative and regulative powers. For example, there are specific requirements to include conservation, environmental problems, health, alcohol and drugs, nature study and outdoor education in educational programs (OSU 120).

Societal goals are sometimes met by elective "popular science" courses. Examples related to biology include: environmental education, ecological studies, and marine biology (CSSE 12:43). Biology is less academically prestigious than either physics or chemistry; however, biology plays a more important role in general education and is responsible for "getting students ready for the biological responsibilities they will face in life" (CSSE 12:20).

Related to societal goals is the "socializing" of students through science teaching (CSSE 12:16, 17; 19:5). Socialization however differs from the conventional notion of a societal goal (OSU 21). Socialization refers to the widely held belief and common practice among teachers that schools are the instruments of inducing conformity of behavior and uniformity of goals in young people. Many science teachers extend the socialization concept to teaching practices; for example, many believe that children should be disciplined to learn expeditiously from textbooks (CSSE 15:6,7). Socialization, therefore, differs radically from the societal goals calling for relevant, issue-oriented biology courses.

Contemporary societal issues are influencing science programs. For the most part, it seems science teachers are developing new courses to meet societal goals and not incorporating societal issues into core or basic courses

in any substantial way. An interpretation of this situation could be the conflict between the disciplinary perceptions of teachers and the interdisciplinary nature of contemporary problems. Discipline-oriented teachers tend to feel that societal issues are "outside their area of responsibility."

#### The Scientific Knowledge Goal

Biology curricula are composed primarily of the knowledge and skills characterizing an academic discipline (CSSE 19:4). In the classroom, knowledge and skills goals become the facts, concepts and principles which reflect the structure of a science discipline (OSU 172). Science teachers report that they want their students to understand the subject matter of science. For example, they want their students to know scientific concepts, to define scientific words, and to demonstrate problem-solving skills. "Understanding" is generally interpreted as passing a test (CSSE 12:3). Science teachers feel that the present heavy emphasis on facts and knowledge is about right (CSSE 12:9). Knowledge of the discipline has been an important goal for two hundred years of American science education. Understanding, as a goal of science, is an aim that is "widely honored, conscientiously pursued and regularly obstructed" (CSSE 12:3).

Scientific knowledge is the only science goal which has been included in the basics movement and, then, very rarely. Declines on composite ACT scores, on the biology achievement tests of SAT, and in science knowledge on NAEP tests are probably factors for putting renewed emphasis on this goal (OSU 172).

TABLE 17  
DISTRIBUTION OF SCIENCE EDUCATION  
COMPONENTS AS REPORTED IN STATE  
GOALS FOR EDUCATION

Component	Number of States Including Component
Facts, Concepts, Principles	17
Process, Inquiry, Investigation	8
Science-Society Interaction	3
Appreciation, Attitude	6
Self and Environment	6

(OSU 173).

In recent years, there has been increased concern for personal, career and societal goals. The federal projects of the 1950's, 1960's and early 1970's were based on Bruner's concept of "the structure of the discipline" - the knowledge and skills important for the discipline of biology. During the 1970's, there has developed a new focus concerning life and work skills, ecological problems and the impact of science and technology on society (OSU 172-175).

Biology subject matter and instructional materials are used for socialization, i.e., the inculcation of values, although this use is not specified in the biology objectives. This may be one of the reasons for the rejection of inquiry strategies and experimental materials (CSSE 19:7). It, along with elitism and concern for college preparation, may also be a reason that personal, societal and career goals are not incorporated into the curriculum (CSSE 12:19).

#### The Career Knowledge Goal

One of the recognized goals of biology education is to provide information and training that will be useful in future employment (OSU 147; CSSE 19:30). Recent concern for this goal is partially due to public opinion (OSU 160) and is constant across all science programs. What matters most in science teaching is: first, the knowledge needed for the next course, and, second, the relationship in the long-run of all courses to one's future job. The "argument is that if knowledge is treated as a collection of pieces, rather than as ideas or models or metaphors, then the vocational relevance of courses can be controlled with the irrelevant pieces trimmed away, or never acquired in the first place" (CSSE 12:22).

There is some resistance to the career preparation goal in science education. Teachers and communities have questioned that a function of schools should be to help labor needs. That is to say, should science help prepare for work? (CSSE 12:22). They have questioned the apparent conflict between the work of the school and the world of work (CSSE 6:53). Science teachers seem to be unwilling to sacrifice the scholastic program in order to get the young prepared for jobs (CSSE 17:21). Furthermore, when teachers, parents and science coordinators are asked about vocational goals of science courses they all agree that they should be included, yet, the majority would select general education goals over vocational goals "if forced to choose between the two" (CSSE 18:107). One obvious omission in most biology curricula is any information which could

help students choose a biology-related career or vocation. The work of scientists (usually historic) is sometimes mentioned, but there is virtually no treatment of biology technology-related careers toward which many students might aspire.

### The State of Objectives for Biology Education

A perennial question for biology educators was first asked by Herbert Spencer in 1854, "What knowledge is of most worth?" Biology educators' answer to this question is represented in their program objectives. Examining the state of biology education begins by reviewing the objectives of current biology programs, and this is one purpose of this section. First, the goals of science teaching are discussed, and next, the related goals of biology education are examined.

In the twenty-year period, 1955-1975, the goals of science teaching have changed little (OSU 170), but presently they are in transition (OSU 21, 190). The science curriculum improvement projects developed during the past twenty-year period focus on goals related to the conceptual structure of scientific disciplines and their processes of inquiry. Throughout this period of curriculum reform, the literature on science education included a number of reports emphasizing the importance of 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 (OSU 170-173, 179-183). In practice, however, the emphasis has been on basic skills, vocabulary and study habits as primary objectives (CSSE 12:5; OSU 192). In the classroom, narrow course objectives (explicit statements of what is to be learned) were used as opposed to general goals (e.g., the nature of inquiry). The latter are more likely found in district objectives (CSSE 12:5). Although there is little evidence that the general stated goals of science education are ever translated into curriculum or classroom practice, it is apparent that teachers do advance such general goals as justification for science instruction (CSSE 2:6, 1:89). The stated goals of science curricula include understanding oneself, appreciating technology, preparing for college science, advancing today's culture and understanding societal issues (CSSE 1:89).

Goal statements such as "the purpose of science is to make better citizens, to study issues in society and to identify science overtones in politics" are appearing (CSSE 2:6). Enrollments have increased in courses with goals oriented toward societal concerns, for example, ecology, marine science, and

oceanography (OSU 25) as well as environmental education and integrated science (OSU 21). These courses include objectives reflecting biosocial issues such as environmental concerns, societal and world problems, decision-making skills, and interdisciplinary concepts (OSU 21).

Generally, teachers show little enthusiasm for teaching biology as inquiry (CSSE 1:42). Instruction directs students to the "right" conclusion and little heed is paid to developing an appetite for submitting beliefs to an empirical test (CSSE 12:9). The curriculum is the textbook, and the objectives are those in the text (CSSE 9:26; 10:24; 13:5, 59, 60; OSU 17). However, in spite of common texts and objectives, there are great differences in biology subject matter from grade to grade, course to course, school to school, and teacher to teacher (CSSE 2:23).

In 1973, Ribble (OSU 172-173) found that 40% of 42 states did not specify goals for the teaching of science and, for those which did, a majority (70%) listed "facts, concepts, principles" and a smaller number (30%) cited "process, inquiry, investigation" as common goals of instruction. Other science teaching goals were cited by only 25% of the respondents or fewer. Compared to information goals all other educational goals are of minor importance.

"The textbook was usually seen as the authority on knowledge" (CSSE 12:1), and for 50% of the science teachers this means a single textbook (RTI 88). Individual teachers or groups of teachers are involved in selecting the textbook used in 98% of the school districts (RTI 99). It is apparent, then, that the biology objectives are those of the biology textbook(s). Only 17% of the teachers feel a need for further assistance in establishing instructional objectives (RTI B-115). Three biology textbooks, Modern Biology and the BSCS "Green" or the BSCS "Yellow" version (RTI 91), represent the textbooks used in two-thirds of the biology classes (RTI B-45) with an enrollment of approximately 3,000,000 students (RTI 61). The extent to which these textbooks also serve as supplementary references in other biology courses cannot be ascertained from the available data.

An analysis of these three biology textbooks for stated objectives and for related major biological topics and concepts was made. The following section is a summary of this analysis. (Refer to Table 1 for a detailed description.)

### BSCS Textbooks

Goals 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 concerning the historical perspective given to the development of biological concepts. The historical perspective provides opportunities to learn about careers through individuals who have made major 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% of the entire text to biosocial issues, the "Yellow" version, a single chapter. The full import of social topics in terms of normative, ethical or value considerations is not considered.

Both of the BSCS texts are oriented toward investigative procedures used in scientific research and the major concepts representing biological disciplines. Specific objectives are identified for each chapter and throughout the textbooks. The objectives tend to represent a range of cognitive levels from simply observing, discussing, or demonstrating to making predictions, synthesizing data and hypothesizing.

### Modern Biology

In general, Modern Biology approaches the structure of biology through factual information arranged phylogenetically. 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 major goal clusters of Project Synthesis, specifically to personal and social problems. Nutrition is a major topic; but, societal issues of 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. The sections on pollution, the environment and conservation introduce these as major problems but avoid treating these issues in the context of personal and social actions.

To summarize, the goals of biology education seem to be in transition reflecting emerging objectives of science education in general. Some restrictive factors, such as the "basics" issues, are having an impact; but more importantly, new objectives of wide educational importance seem to be emerging from social and personal concerns, (e.g., ecology and the environment) and from efforts to improve the "quality of life." Texts are the curriculum, and the analysis of the major biology texts reveal that they include objectives related more to older goals such as "the structure of a discipline." They do not emphasize in a substantial way goals related to contemporary biosocial issues.

#### Actual Biology Education Programs

Thus far, the existing goals and objectives of biology education have been described. The next question is, "To what extent do curriculum programs represent the stated goals of biology education?"

Changes in biology programs are being influenced by two important factors. One dominant factor is the back-to-the-basics movement (CSSE 19:2; OSU 147, 149). The "basics" is perceived as reading, writing and mathematics (CSSE 19:2-3). It would seem that existing science programs tend to address the "basics" of science since they are primarily knowledge and skills oriented, grounded in academic descriptions of science (CSSE 19:4-5). However, science itself is not considered "basic," and many biology teachers feel there is a shift away from science subjects. However, only 7% of science teachers rated "belief that this subject is less important than other subjects" as a serious problem. Thirty-nine percent thought this attitude was somewhat of a problem, and 51% indicated it was not a significant problem (RTI 158).

The direction of change in biology programs is further confused by a second factor, namely, science and society issues (OSU 21). Such issues were largely neglected in NSF science-improvement curricula programs of the 1960's (OSU 24). Response to the concern for social issues is perhaps best represented by the rapid expansion of earth science programs between 1965-1975 and the implementation of environmentally and ecologically oriented courses in the biological sciences during the same time period.

Biology teachers were asked to rank in order of importance problematic factors influencing their teaching. Lack of materials for individualized instruction was ranked first; insufficient funds and inadequate facilities were ranked

TABLE I  
OBJECTIVES OF CONVENTIONAL BIOLOGY PROGRAMS  
AS REFLECTED IN THE TEXTBOOKS MOST WIDELY USED IN SCHOOLS

	<u>BSCS YELLOW</u>	<u>BSCS GREEN</u>	<u>MODERN BIOLOGY (1973)</u> <u>OTTO, TOWLE MADNICK</u>
<b>GOAL:</b>	<u>Science as Inquiry and Investigation</u>	<u>An Understanding of the Nature of Scientific Inquiry</u>	<u>(Biological) Science is a Body of Knowledge (p. 3)</u>
<b>OBJECTIVES:</b>	<p>Make specific observations regarding a biological phenomenon (p. 4)</p> <p>Develop a hypothesis to explain the observations thus made (p. 4)</p> <p>Demonstrate how data can support or not support the validity of an hypothesis (p. 4)</p> <p>Conduct a simple biological experiment (p. 4)</p>	<p>Identify in a given investigatory situation the elements of scientific procedure (p. T3B)</p> <p>Construct hypotheses appropriate to a given problem (p. T3B)</p> <p>Discuss the values of measurement in scientific investigation (p. T3B)</p> <p>Explain the meaning of a variable (p. T3B)</p>	<p>Name the five stages in the life span of an organism (p. 13)</p> <p>Define the terms matter and energy (p. 26)</p> <p>Describe the structure of the atom (p. 26)</p> <p>Explain the functions of carbohydrates, lipids, proteins and nucleic acids (p. 26)</p> <p>Understand Mendel's law of independent assortment (p. 97)</p>
<b>GOAL:</b>	<u>The History of Biological Concepts and Discoveries</u>	<u>An Understanding of the Limitations of Science and of the Scientific Method</u>	<u>Biology is also the Logical, Scientific Method (p. 3)</u>
<b>OBJECTIVES:</b>	<p>Compare the hypothesis of Aristotle with that of William Harvey regarding the circulation of the blood (p. 66)</p> <p>Describe the evidence used by Harvey concerning the functioning of valves in veins (p. 66)</p> <p>Describe the experiment of Loewi and what it contributes to our understanding of motor neurons (p. 83)</p> <p>Relate the contributions of John Ray and Carolus Linnaeus to the concept of species (p. 100)</p>	<p>Distinguish between speculations and theories (Chapter 10)</p> <p>Describe the environmental conditions in which life may have originated (Chapter 10)</p> <p>Explain how biochemical experiments have provided a degree of plausibility for speculations on the biochemical origin of life (Chapter 10)</p>	<p>Demonstrate the use of the scientific method (p. 3)</p> <p>Explain the limitations of the light microscope (p. 3)</p> <p>Explain the advantages of the electron microscope (p. 3)</p> <p>Describe the bases of scientific classification (p. 163)</p> <p>Demonstrate the ability to classify an organism (p. 163)</p>

NOTE: These BSCS Yellow and BSCS Green goal statements are from the first commercial edition (1963) and were included in the edition used for this comparison, Third Edition (1973)

TABLE 1 (continued)

	<u>BSCS YELLOW</u>	<u>BSCS GREEN</u>	<u>MODERN BIOLOGY</u>
<b>GOAL:</b>	The Genetic Continuity of Life	Our Understanding of the Diversity of Life of the Interrelations of all Organisms	Biology Arose from the Human Need to Understand Events and Solve Problems (Social) (p. 3)
<b>OBJECTIVES:</b>	Describe the pathways involved in the coordination of breathing, including the organs affected by the coordinators (p. 82)	Recognize a variety of structural adaptations in familiar animal species (p. T89)	Describe sickle-cell anemia (p. 127)
	Identify genotype and phenotype (p. 194)	Predict the environment in which unfamiliar animals might suitably live, given a set of selected structural adaptations (p. T89)	Understand the inheritance of mental disorders (p. 127)
	Compare the terms heterozygous and homozygous (p. 194)	List plant groups that may be found in such habitats: marshes, deserts, seaways (p. T145)	Explain the genetic basis of Down's syndrome (p. 127)
	Define allele and gene (p. 194)	Infer functional differences from observing differences in plant structure (p. T145)	Describe the effects of smoking on the body (p. 597)
	Describe the life cycle of <i>Drosophila</i> (p. 194)		Describe the effects of alcohol on the body (p. 597)
			Discuss alcoholism as a disease (p. 597)
			Understand some of the causes of drug addiction (p. 597)
<b>GOAL:</b>	<u>Change of Living Things Through Time: Evolution</u>	<u>An Appreciation of the Beauty, Drama and Tragedy of the Living World</u>	<u>Biology has grown from the Work of Many People in Many Different Lands (History) (p. 3)</u>
<b>OBJECTIVES:</b>	Summarize the evolution in green plants (p. 133)	Explain the effects of mankind's developing technology on the extension of the ecosystems of which particular human populations were a part (p. T661)	Explain the roles of Redi and Spallanzani in the theory of spontaneous generation (p. 13)
	Describe the conditions necessary for the formation of fossils (p. 231)	Relate wastes to resources (p. T661)	Describe Pasteur's experiment that proved biogenesis (p. 13)
	Explain why fossils are relatively rare (p. 231)	List at least 5 categories of substances that are currently regarded as wastes (p. T661)	Describe how Koch investigated an unknown disease (p. 195)
	Explain why a virus could represent an early stage in the evolution of organisms (p. 231)	Describe the problems of disposal posed by at least 3 of these (p. T661)	Describe the contributions of Edward Jenner (p. 195)
	Identify the age of the oldest fossils of which there is a record (p. 231)	Apply the idea of "trade-off" to at least one waste-disposal problem (T661)	

TABLE 1 (continued)

	<u>BSCS YELLOW</u>	<u>BSCS GREEN</u>	<u>MODERN BIOLOGY</u>
<b>GOAL:</b>	Diversity of Type and Unity of Pattern among Living Things	An Understanding of the Biological Bases of Problems in Medicine, Public Health, Agriculture, and Conservation	Our Society Accepts and Supports Modern Science (p. 4)
<b>OBJECTIVES:</b>	<p>Give examples of the sites from which sensory neurons pick up messages (p. 83)</p> <p>Recognize reproduction as essential only for perpetuation of the species not for the life of the individual (p. 92)</p> <p>Describe three common patterns of sexual reproduction (p. 92)</p> <p>Relate sexual reproduction to the process of evolution (p. 92)</p>	<p>Distinguish between the two principal means of controlling behavior (p. T479)</p> <p>Describe the chemistry of a synapse (p. T479)</p> <p>Distinguish among the physiological activities of stimulants, tranquilizers, and hallucinogens (p. T479)</p> <p>Explain the dangers to an individual of self-administration of drugs (p. T479)</p> <p>Extrapolate these individual dangers to effects on human social organization (p. T479)</p>	<p>Understand the universal nature of science (p. 3)</p>
<b>GOAL:</b>	Regulation and Homeostasis: The Preservation of Life in the Face of Change	An Understanding of the Historical Development of Biological Concepts and Their Dependence Upon the Nature of Society and Technology of Each Age	
<b>OBJECTIVES:</b>	<p>State why oxygen is essential to most living cells (Chapter 12)</p> <p>Distinguish between respiration and breathing (Chapter 12)</p> <p>Describe the part diffusion plays in respiration in a single-celled organism such as Paramecium (Chapter 12)</p> <p>Identify the primary source of oxygen for all animals (Chapter 12)</p>	<p>Order chronologically 3 or 4 principal events in the discovery of the cellularity of organisms (p. T345)</p> <p>State the three principal parts of the cell theory (p. T345)</p> <p>List 4 or more major discoveries that led to our present understanding of photosynthesis (p. T369)</p> <p>Relate Mendel's observations to the chromosome theory of heredity (p. T539)</p>	

TABLE 1 (continued)

	<u>BSCS YELLOW</u>	<u>BSCS GREEN</u>
GOAL:	<u>Growth and Development in the Individual's Life</u>	<u>An Understanding of Man's Own Place in Nature: Namely, that He is a Living Organism, that He has much in Common with Other Organisms and that He Interacts with All Organisms in the Biological System of Earth</u>
OBJECTIVES:	<p>Contrast development and fertilization (p. 225)</p> <p>Identify four processes of development (p. 225)</p> <p>Relate mitosis to growth (p. 225)</p> <p>Describe the consequences of cellular differentiation (p. 225)</p>	<p>Name organisms that owe their present distributions to man's (1) deliberate and (2) accidental agency (p. T231)</p> <p>Describe 3 or more examples of man's alteration of natural biomes (p. T231)</p> <p>Explain man's effects on ecosystems in terms of succession (p. T231)</p> <p>Describe at least 3 major ways in which man has physically changed inland-water ecosystems (Chapter 9)</p> <p>Explain the changing effects of a sewage inflow along a length of river. (Chapter 9)</p> <p>List at least 4 kinds of things that, when added to natural waters by man, reduce the biotic potential of those waters (Chapter 9)</p>
GOAL:	<u>The Complementarity of Structure and Function</u>	
OBJECTIVES:	<p>Describe the necessity for coordination within a multi-cellular animal (p. 82)</p> <p>List three conditions necessary for coordination (p. 82)</p> <p>Recognize the two major coordinating systems in the human body (p. 82)</p> <p>Explain how the breathing mechanisms that maintain constant concentrations of oxygen and carbon dioxide relate to the theme of homeostasis (p. 82)</p> <p>Recognize the neuron as the unit of structure and function in the nervous system (p. 82)</p>	
GOAL:	<u>The Complementarity of Organizational Environment</u>	
OBJECTIVES:	<p>Identify how primitive man used artificial selection in the origination of cultivated plants (Chapter 34)</p> <p>Describe some centers of origin of important crops and domestic animals (Chapter 34)</p> <p>Describe the specific relationship that man has to his environment which is different from that for other animals (Chapter 34)</p>	
GOAL:	<u>The Biological Basis of Behavior</u>	
OBJECTIVES:	<p>Relate which of our unique abilities can be ascribed to the functioning of our brains (p. 83)</p> <p>Give examples of conscious and unconscious activities controlled by the central nervous system (p. 83)</p>	

second and third respectively (RTI 159). There are also other problems contributing to concerns about biology programs. A number of NSF curricula have proved difficult for average and below average students. The difficulty is due to high reading levels and the difficulty of the concepts (OSU 35). Junior high school science teachers have indicated that there are fewer programs available, and the programs are less appropriate for their students' needs (OSU 95). Another curriculum problem is the influence of state regulations. On the one hand, new courses have been required that relate to societal issues and are aligned with the biological sciences, e.g., ecology (OSU 120). On the other hand, state regulations have reduced the amount of science required for graduation, they have indirectly reduced money for science programs, and in some cases, they have eliminated programs (OSU 120-121).

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 goals in a human context and career awareness are only minimally treated in the subject matter of the textbooks.

The middle/junior high school life science curriculum has been reconstructed from textbooks used most commonly in the intermediate grades as identified in the RTI survey (see Table 2). This approach is well-grounded as a means of evaluating existing programs since 90% of intermediate teachers base their instruction on a single text (OSU 17). These books have been examined qualitatively to determine the emphasis on the major goals: inquiry, personal and societal needs, scientific knowledge and career awareness. The authors' educational goals for their textbooks have been reviewed as well as their approaches to laboratory-type activities.

The stated goals were typically the following ones: (1) to present information representative of biological 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, importance of 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 goal that dominated all of the middle/junior high school programs was the acquisition of biological information. The major emphasis was upon acquiring 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. Knowledge was interpreted as recall of facts. In several of the textbooks an effort was made to have students organize their learning in terms of broader concepts such as the relationship of living things to their environment, the distinction between a "simple" plant or animal and a "higher" plant or animal, or the importance of a taxonomic system.

Laboratory activities were typically distributed throughout the textbooks. As opposed to reading to get information, these activities required the learner to be physically involved by doing such things as sprouting bean seeds, observing the parts of a plant or animal, taking one's temperature or comparing several related organisms. Textbooks also presented some experimental activities in which students were asked to answer a question or solve a problem by gathering and interpreting information in an organized way. In experiments, students were required to measure, count, or describe observations in some quantitative way. In a minority of textbooks (e.g., ISCS and Interaction of Man and the Biosphere), there was a special effort to make the laboratory activities an integral part of learning; this approach, however, was not typical.

The study of the human species in middle/junior high school textbooks was limited to a knowledge of anatomy and the functioning of various systems. Such topics as genetics, behavior, reproduction, development and "history of life on earth" (evolution), frequently had a reference to human beings, but were never central to the study of the topic. However, disease, nutrition, drugs, and health topics were typically considered in a human and personal context.

Biosocial problems such as conservation, pollution, energy shortages, water purity, use of insecticides, and overpopulation were generally grouped in a single chapter located near the end of the textbook. The problems were identified

and described but were not explored either in terms of conditions necessary to resolve the issues or in terms of individual responsibility for appropriate action. At various places in many of the textbooks, there were supplemental questions to chapters suggesting students might want to study a biosocial problem in personal terms.

In the middle/junior high school programs, there was little attention given to information on different careers in the biological sciences. Textbooks did provide photographs of famous biologists and descriptions of the scientific contributions made by those individuals. The extent to which this material was made a part of the instruction is not evident from the textbooks.

In most ways, the middle/junior high school life science programs, in subject matter and organization, were mirror images of high school biology textbooks. The reading level was usually lower than that of a high school textbook and terms were defined in more detail. However, in a small number of junior high schools (about ten percent), a biology program was offered in the ninth grade that used a textbook commonly used in senior high schools.

To summarize, existing biology education programs are apparently under social pressure to change. The direction of changes is, as yet, unclear. 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. There is little attention given to personal needs and social issues related to biology.

#### Program Dissemination

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. One way teachers and principals have learned about new biology programs is by attending NSF institutes. These institutes for teachers and administrators have attracted slightly more than 20% of the principals of grades 7-9 and 10-12, 32% of the teachers of grades 7-9, and 47% of the 10th-12th grade teachers (RTI 69, 71). The proportion of teachers

TABLE 2

SENIOR HIGH SCHOOL AND MIDDLE/JUNIOR HIGH SCHOOL TEXTBOOKS ANALYZEDGrades 10-12

- Biological Sciences Curriculum Study, Biological Science: An Ecological Approach, (BSCS Green Version, 3rd edition), Rand McNally and Co., N.Y., 1973 (teacher's edition)  
(Also, 4th edition, copyright 1978)
- Biological Sciences Curriculum Study, Biological Science: An Inquiry into Life, (BSCS Yellow Version - 3rd edition), Harcourt Brace Jovanovich, Inc., 1973  
(Also, separate teacher's manual)
- Otto, James H., Albert Towle, and Myra E. Madnick, Modern Biology, Holt, Rinehart and Winston, N.Y., 1977 (teacher's edition)
- Otto, James H., Albert Towle, W. David Otto and Myra E. Madnick, Laboratory Investigations in Biology, Holt, Rinehart and Winston, N.Y., 1977.
- Otto, James H., Albert Towle, W. David Otto and Myra E. Madnick, Biology Investigations, Holt, Rinehart and Winston, N.Y., 1977

Grades 7-9

- Abraham, Norman, Richard G. Beidleman, John A. Moore, Michael Moores and William J. Utley, Interaction of Man and the Biosphere, Rand McNally and Co., N.Y., 1975 (teacher's edition)
- Blanc, Sam S., Abraham S. Fischler and Olcott Gardner, Modern Science: Earth, Life and Man, Holt, Rinehart and Winston, Inc., N.Y., 1971 (teacher's edition)
- Brandwein, Paul F., R. Will Burnett and Robert Stollberg, Life: Its Forms and Changes, Harcourt, Brace and World, Inc., N.Y., 1968
- Heimler, Charles H. and Charles D. Neal, Principles of Science - Book One, and Principles of Science - Book Two, Charles E. Merrill Publishing Co., Columbus, Ohio, 1975 (teacher's edition - 3rd edition)
- Heimler, Charles H. and J. David Lockard, Focus on Life Science, Charles E. Merrill Publishing Co., Columbus, Ohio, 1977 (teacher's edition)
- Intermediate Science Curriculum Study (ISCS) Investigating Variation (Probing the Natural World/Level III), Silver Burdett, Morristown, N.J., 1972 (teacher's edition)
- Intermediate Science Curriculum Study (ISCS) Well Being, Silver Burdett, Morristown, N.J., 1972 (teacher's edition)
- Intermediate Science Curriculum Study (ISCS) Why You're You, Silver Burdett, Morristown N.J., 1972 (teacher's edition)
- Intermediate Science Curriculum Study (ISCS) A Matter of Strength, Silver Burdett, Morristown, N.J., 1972 (teacher's edition)
- Navarra, John Gabriel, Joseph Zaffaroni and John Edward Garone, Life in the Environment, Harper and Row, N.Y., 1973
- Otto, James H., Albert Towle, and Myra E. Madnick, Modern Biology, Holt, Rinehart and Winston, N.Y. 1977 (teacher's edition)
- Otto, James H., Albert Towle, W. David Otto and Myra E. Madnick, Laboratory Investigations in Biology, Holt, Rinehart and Winston, N.Y., 1977
- Otto, James H., Albert Towle, W. David Otto and Myra E. Madnick, Biology Investigations, Holt, Rinehart and Winston, N.Y., 1977
- Tater, Harold E., Thomas D. Bain, Frederick L. Fitzpatrick, Living Things, Holt, Rinehart and Winston, N.Y., 1977 (teacher's edition)

attending an institute is not constant throughout the United States; those (of grades 7-9) in the West have attended more institutes than those in other regions (RTI 70). More than two-thirds of the state supervisors of science have attended one or more NSF programs, such as, summer institutes (69%), inservice (18%), academic year institutes (30%), administrator conferences (30%), and leadership development projects (30%) (RTI 61, 70 and B-8). Of those persons generally responsible for local science curriculum development for grades 7-12, 40% have attended an NSF summer institute, 18% an inservice program, and fewer than 10% any other type of special program (RTI B-9). Ten percent of school principals (grades 7-9) attended NSF summer institutes and 5% inservice programs. These are the two NSF activities in which principals participated most. The percentages of high school principals participating in these two activities were 20% and 8% respectively. These figures do not necessarily mean that the given NSF program was oriented to biology or even to science in general (RTI B-10). Among the many NSF programs available, the NSF summer institute programs have been the most widely attended by administrators, supervisors, and teachers of math, social studies and science and, therefore, have been significant forces affecting program dissemination (RTI B-11).

Half of the states have a means, through the state science supervisor, for disseminating information about new biology programs. Knowledgeability of sources of curriculum materials is seen as an important characteristic of curriculum supervisors by 89% of science supervisors for grades 7-12 (CSSE 16:45). The major sources of information for state supervisors were publishers and sales representatives (sources for 84% of supervisors), journals and other professional publications (76%), meetings of professional organizations (67%), federally sponsored workshops (65%), teachers (54%); all other categories of information were each reported to be used by less than 50% of supervisors (RTI 73, B-13).

The local curriculum respondents for grades 7-12 received their information about a new science program from publishers (63%), teachers (62%), journals and professional publications (61%), college courses (49%), and professional meetings (44%); other sources were of lesser significance, being under 32% (RTI B-14). Grades 7-9 science teachers reportedly learned about new science programs mostly from other teachers (66%) and from college courses (53%), followed by publishers (37%). Approximately one-fourth of these teachers got their information on a new curriculum from a subject specialist (26%), a federally sponsored

workshop (23%), or a professional publication (28%). Inservice programs were not a frequent source of information (18%) (RTI B-15). As financial support has tightened, the number of science consultants available to help teachers has decreased in number. Inservice efforts generally take the form of staff meetings, special inservice days, and enrollment in university courses. A decline in such programs is explained by (1) fewer inexperienced teachers, (2) less incentive for gaining credits and degrees, and (3) fewer dollars for resource persons (CSSE 16:48). Teachers, however, continue to be interested in help from universities. Science teachers of grades 7-9 want (1) help with curriculum development (43%), (2) special inservice workshops made available (16%), and (3) courses specifically oriented to teacher needs (12%) (CSSE 16:49).

To see or learn about a new science program is important, but is the information of much value or use? Fifty-two percent of teachers of grades 7-9 perceive the information they obtain from other teachers to be "very useful" while 54% of the 10-12 teachers rate such information only "somewhat useful." Forty-nine percent of the teachers of grades 7-9 rate professional journals and college courses as "very useful," while 54% of the grades 10-12 teachers give similar ratings (RTI B-118). Although half of the teachers rate professional journals their most useful source of information (RTI B-118), only 63% of grades 7-9 science teachers and 78% of 10-12 science teachers read such journals (CSSE 18:24). The number of education articles read per month by those who do read professional journals is 5.5 articles and the number of articles on science or science teaching read is 12.1 per year (CSSE 18:24). The average number of education books read by 7th to 9th grade science teachers per year is 5.1, and of books about science the average is 4.4 for the same teachers (CSSE 18:24).

Federally sponsored workshops are seen as "very useful" by 26% of the 7-9 teachers and by 29% of the 10-12 teachers. Approximately, one teacher in five finds the information obtained at professional meetings and from inservice programs "very useful." Information about new programs obtained from other sources is rated "very useful" by fewer than 15% of the teachers; these sources include: principals, local subject specialists, state department personnel, teacher union meetings and publishers (RTI B-118). A survey of 535 grade 7-9 science teachers reveals that only 37% of the teachers found professional journals "particularly useful" (RTI 156).

The network of communication about new curricula and instructional materials centers upon professional publications and professional meetings where the source of information is combined with the usefulness of the information obtained. Teachers themselves are a major link in the communication network as a source of information not only for each other but for curriculum coordinators, supervisors, and principals. What is not so clear is the source of teachers' original information about a new program; one suspects there is a variety of sources. NSF summer-institute programs and college courses are also important parts of the communication network. Although commercial organizations appear to be an important source of information, they are not judged to be the most useful to school personnel.

#### Program Adoption

-Biology is offered in 95% of the schools with grades 10-12 and in 30% of the junior high schools (grades 7 through 9). Advanced biology is offered in 47% of the schools with grades 10-12. Environmental studies is an offering in 16% of the schools with grades 10-12 (RTI 53). Other biology-related courses offered include oceanography, marine science, ecology, physiology and integrated science. The increased number of biology offerings may be a possible explanation for the slight decrease in students enrolled in a course entitled "Biology" (OSU 26) over the past decade. Currently, three million students are enrolled in a tenth or eleventh grade biology course and well over one million in junior high school life science courses (OSU 27; RTI 61).

The biology program at grade 10 consists of the course as outlined in Holt's Modern Biology and as in the BSCS "Green" and "Yellow" versions. These three texts describe biology for 80% of the students enrolled in general biology (OSU 26). The teacher is the primary determinant of the textbook used (CSSE 19:2; RTI 99). Hence, program adoption depends upon teacher opinion. The principal and community attitudes (RTI 159) are also factors in program adoption.

Biology is the only science area in which significant numbers of teachers chose to use one of the new programs of the 1960's, i.e., one of the BSCS versions. A total of 53% of the districts have used one of the three (including the "Blue" version) BSCS versions (RTI 85). Currently, use of the BSCS basic courses is declining as is the use of other products of the curriculum reform movement of the 1960's, with the greatest decline at the ninth grade level. The conceptual level of such curricular materials including those of BSCS resulted in problems of implementation (CSSE 13:11; OSU 181).

Program ExposureCourse Offerings

The most common science course in the high school curriculum is biology, usually offered as a tenth grade course. It is offered in 95% of the schools (RTI 53) and serves over 80% of all students in the secondary school (OSU 26). Biology (or life science) is also offered in 30% of the junior high schools (grades 7-9).

Biology for more able students is sometimes offered in grade nine. Such tracking allows scientifically inclined students to complete more science electives in grades 10-12. Such an offering (often a BSCS version) is usually a course similar to the tenth grade course but taught as a college preparatory course for the most capable students. Such "segregation" of students thus begins in the junior high and paves the way for an advanced senior high sequence (CSSE 12:1). A side effect of such "tracking" or "grouping" of students by ability, by occupational intention, or by prerequisite knowledge may be segregation by race or by sex. For example, 60% of the students in the lowest level of science in a Texas school were black males, assigned first because of a reading problem, second because of a math problem, third because of a discipline problem, and last because of a science problem (CSSE 15:40). Furthermore, many minorities do not take science courses because they have not been counselled into the academic "tracks" or into the prerequisite mathematics courses.

Special interest courses in ecology, anatomy, oceanography, physiology, human biology, integrated science, and environmental studies are clearly "biology" offerings. These courses are attracting increasing numbers of students and, thereby, are becoming collectively important in terms of the biology curriculum and kinds of students served (OSU 24). Programs emphasizing the interaction of science and society are attracting students not previously served in the science program (OSU 21); at times such offerings may cause a decrease in enrollment in general biology (OSU 26). The increasing diversity in biology offerings provides a wider science experience for students (CSSE 13:3). Between schools, and within schools, there is a great variation in the number of course offerings; for example, some high schools may offer as few as five and other schools as many as 18 courses in different fields of biological science (CSSE 13:3).

Advanced biology is offered in 47% of all schools with grades 10-12 (RTI 53). This offering is clearly for college preparatory students, usually for

those interested in medicine or health-related programs. Such programs illustrate the high priority schools and teachers give to advanced courses and to servicing college-bound students (CSSE 12:1).

#### Requirements

Although science is a common requirement in junior high school, and many high schools have a one-year graduation requirement (OSU 37), only 49% of the school districts require a specific course in science in grades 9-12. Twenty-one percent require biology (RTI 26). Many schools (21%) require more than one year of science (RTI 24). In most instances students elect a course in the biological science area to fulfill general graduation requirements (OSU 26). Since nearly one-third of the schools include life science as a junior high school course, it can be assumed that this is essentially another "biology" requirement in the secondary school.

#### Time Allotments

Time allotments for science tend to increase as the grade level increases (RTI 51). In junior high school, it is common to have science on a daily basis for 40 to 50 minutes. The length of time for general biology and other "biology" offerings in the 10-12 grades ranges from 45 to 60 minutes daily. Almost all of the biology courses in grades 7-12 are year-long courses, while 88% of all courses in grades 10-12 are one-year courses (RTI 65). Semester courses in life science are found in 7% of the schools at grades 7-9; this figure is 6% for grades 10-12. Life science courses offered on a quarterly basis are found in 4% of the secondary schools.

#### Enrollments

Biology is offered to all students (CSSE 19:3) with nearly three million students enrolled each year (OSU 27; RTI 58, 61). Since biology is often viewed as "required," it is a course serving the general population, usually at the tenth grade level. Each year, 80% of graduating seniors have completed a course in biology (OSU 26). For 50% of the students graduating each year, biology represents their last experience with science (OSU 3-26, 36).

Life science is frequently offered as a part of the junior high program where over a million and a quarter students are enrolled each year (RTI 58). When one views special courses in biology, i.e., physiology, ecology, environmental studies, oceanography, and others, over 600,000 additional students are

enrolled each year. There have been substantial increases in enrollments in such elective biology courses during the last five years (OSU 29); also, the percentage of student enrollment in general biology in grades 10, 11, and 12 increased from 1955 through the early 1970's (OSU 26).

### Teacher Characteristics, Training, Certification

#### Characteristics

A general picture of biology teachers is derived from three NSF science status studies. All science teachers were included in the sample polled (RTI 9). Since biology classes enroll two-thirds of all science students (RTI 61), the assumption is made that biology teachers composed two-thirds of the sample of science teachers of grades 10-12. There were approximately 36,000 biology teachers in the United States in 1971. A biology teacher is defined as a person who has an undergraduate degree in biology and who teaches 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 (BSCS, 1978: 71).

In many schools, science teachers are reported to have the most stability regarding assignment and longevity and to occupy a position of academic prestige within the school's hierarchy (CSSE Vol. I). Although biology teachers are viewed as holding less prestigious positions than physics and chemistry teachers, they are, nevertheless, part of an elitist group. Furthermore, biology teachers who teach an advanced placement course are near the peak of professional status in any school's social system (CSSE 16:8).

Generally, the average number of years of experience for science teachers (grades 10-12) is 11.8 (RTI 138); and, in grades 10-12, 74% are men, while 24% are women (RTI 141). However, it may be assumed that most of the women teaching science are biology teachers.

While 85% of science teachers in grades 10-12 teach all of their courses within a single science area, only 76% of 7-9 science teachers do so (RTI 142). One way of improving junior high science teaching might be to assign teachers full time to their discipline (OSU 89). Currently, approximately 13% of secondary science teachers are teaching at least one course for which they feel inadequately qualified, and usually these courses are within the science area (RTI 142).

The role of the teacher as central to science instruction is evident: first, teachers have autonomy in how science is taught (CSSE 13:3); second, teachers' beliefs and attitudes are important keys to the instruction they provide (CSSE 19:2); third, few teachers engage students in learning by experience (CSSE 15:7); fourth, teachers are not "model inquirers" (CSSE 12:8); and, finally, individual science teachers make identical courses appear to be different (CSSE 13:3). Although teacher styles and strategies are as varied as curriculum content and format (CSSE 13:3), teachers are the source of power within the classroom (CSSE 13:59). Furthermore, many science teachers are characterized as authoritarian (CSSE 16:26.3, 19:5). Science teachers have indicated increasing dissatisfaction with their roles; many see an erosion of their place as the "academics" of the high schools (CSSE 7:36). For example, they complain of extra duties; i.e., of hall and lunchroom patrols (CSSE 1:76).

Science teachers, generally, are perceived positively by their students. For example, 76% of 13-year-old students and 81% of 17-year-old students reported that their most recent science teacher "really likes science;" and approximately 50% at both age levels said that their science teachers are enthusiastic and make science exciting (NAEP COLT02).

#### Professional Attributes

Generally, science teachers conform to the value system of the communities in which they work (CSSE Vol. I), and this conformity is reinforced by hiring procedures (CSSE 17:5, 19:17). In most instances, teachers closely fit the neighborhood's majority group image of what a teacher should be professionally (CSSE 17:5). Within their classroom, teachers avoid discussions of controversial subjects and cling to their posture of authority in order to maintain "their social rank, their podium and their seats of judgment" (CSSE 12:10). Contrary information, however, is found in the 1977 NAEP results which indicate that students perceive their teachers as willing to share their opinions on population, pollution, and other value-laden topics (NAEP COLT02).

#### Professional Affiliations

Most biology teachers belong to organizations or unions; for example, 80% of pre-college teachers belong to an AFT or an NEA affiliate (CSSE 3:5); six thousand belong to the National Association of Biology Teachers, a professional organization specifically for biology teachers. Furthermore, science teachers demonstrate their professionalism in their reading patterns; science teachers at

all grade levels report more reading of professional books and articles than teachers of other disciplines (CSSE 18:23).

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 (CSSE B:5). Some professional organizations stress professional ethics and the welfare of the child, while others push for raising certification standards to admit fewer teachers. Teachers are increasing their militancy as a reaction to "riffing", a term applied to 'reduction in teaching forces' (CSSE B:4) and to the reassignment of teachers (CSSE B:5). For example, there were 468 teacher strikes from 1973 to 1975, and issues such as out-of-class duties, class size, and tenure by building have been added to the negotiation docket (CSSE B:5). Teachers, unless they benefit directly, have little enthusiasm for affirmative action (CSSE 17:5). 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. Schools, and science departments, have diminishing control over the most important determinant of good learning, the teaching positions (CSSE 17:4).

### Training

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 (OSU 91). The median requirement of biology courses for certification is twenty-four hours (OSU 54). However, 21% of biology classes are taught by teachers with less than 18 hours in biology (OSU 83). The undergraduate courses taken by teachers are the same courses taken by students preparing for graduate professional schools. Therefore, teachers receive little education in responding to fruitful observations or to penetrating questions from their thoughtful students (CSSE 16:8). The infrequent use of creative inquiry teaching in science classrooms seems to be related to the fact that teachers rarely experience it in their college preparation (CSSE 12:7).

The professional component of preservice education is basically divided between instruction in elementary and secondary education; few institutions have programs specifically designated for middle/junior high school (OSU 63). Recently, there have been indications that topics such as "humanism, relating science to

contemporary social problems and issues, extended field-based experiences, and involvement with inner-city students and other minority groups" have been included in preservice professional courses (OSU 57). However, a survey of science methods courses reveals little impact of the NSF-funded biology curricula. Only 30% (of the 922 colleges and universities surveyed) reported studying the BSCS curricula intensively and less than 10 of the 342 courses studied in detail used the BSCS Biology Teachers Handbook as a professional textbook (BSCS 60:8). The final preparation for teaching student teaching, is most often reported to be full-time for less than a semester (OSU 64).

Generally, preservice teacher preparation was found to be characterized by the following attributes described in the NASDTEC-AAAS Guidelines (AAAS Miscellaneous Publication 71-9, Washington, D.C., 1971):

1. Breadth and depth of science preparation;
2. Minimal mathematics competencies;
3. Nature of learning and its application to science teaching.

On the other hand, the following attributes described in the Guidelines were found to be lacking:

1. Seeking out ideas in science new to the prospective teacher and communicating them;
2. Societal issues;
3. Interdisciplinary and philosophical issues. (OSU 46-74).

Inservice. Seventy-two percent of secondary science teachers hold bachelor degrees, mostly in biology. Many teachers return to colleges and universities for advanced degrees (OSU 91); more than one-half of science teachers have master's degrees (OSU 91). Furthermore, more than 75% of science teachers have taken more than ten hours of graduate work, and less than 40% have taken graduate work in the science they are teaching (OSU 82-83). In past years, the NSF-funded summer and academic year programs have been popular with science teachers. For example, over 50% of them have attended one or more NSF summer institutes, while 9% 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 regions (OSU 93; RTI Table B.7). These participants were more likely to use NSF curricular materials and laboratory activities in their classrooms and to stress student-centered activities (CSSE 18:23; OSU 92). Furthermore, there has been a consistent trend toward better student performance with increased teacher NSF participation (OSU 103).

Teachers are very specific in identifying needed areas of inservice training. They feel that inservice activities should have the following characteristics:

1. Involve short, summer institutes
2. Stress curriculum techniques, such as the use of evaluation, to diagnose difficulties
3. Emphasize individualized instruction
4. Emphasize careers (OSU 95-96).

Furthermore, when teachers are asked what the federal government can do to support secondary science education, they rank the following inservice activities the highest:

1. Hire and pay resource people to help teachers with their teaching skills
2. Provide additional institutes
3. Develop science courses oriented to careers
4. Provide free or inexpensive films and lab materials to schools.

The following services have been ranked near the bottom:

1. Provide free telephone networks for teachers to help other teachers
2. Undertake a public campaign to promote scientific literacy
3. Subsidize early retirement of ineffective teachers (CSSE 16:49)

The following demographic data bear directly upon inservice teacher programs. Although the Ohio State study indicates that 35% of science teachers have entered the profession in the last five years (OSU 90), data collected by the RAND Corporation showed that, on the average, in 1971, science teachers were considerably older than other secondary teachers. It is predicted, therefore, that there will be a wave of retirements in the early 1980's. RAND estimates the average age of science teachers in 1981 to be the following:

<u>Age</u>	<u>1981</u>
Below 30	15.6%
30-39	29.3
40-49	32.2
50-59	22.9
60+	2.7

This information is important to NSF because the studies indicate that younger teachers are more likely to attend NSF institutes (OSU 191), and a higher percentage of younger teachers will be entering the science teacher ranks shortly.

### Certification

Although certification requirements are basically the prerogative of each state, within most states certification is based primarily on the "approved program" format by which the institution, not the state, makes recommendations for certification (OSU 50). Furthermore, most states extend reciprocity to persons certified by other states (OSU 50). After Sputnik (1957) there was a general trend toward more science courses and fewer professional courses for state certification (OSU 54); certification requirements in biology range from 15-42 semester hours (OSU 54).

Certification patterns still are based largely on courses completed rather than upon classroom performance, despite the increase in articles emphasizing competency or performance-based teacher education (OSU 50). Upon completion of an approved undergraduate biology teaching program, the preservice teacher is awarded a basic or provisional certificate effective for several years. This certificate may be renewed or exchanged for a more permanent license upon the completion of several years' teaching experience and/or evidence of additional academic work. There is a great deal of flexibility and variety in requirements concerning the nature of this advanced work, not all of which needs to be part of a degree program or in the teacher's subject area (OSU 50-51).

### Summary

Basically, the characteristics, training and certification requirements of biology teachers are mixed. Their preservice preparation is determined by individual colleges and universities, their professional certification is controlled by individual states, and their inservice training is, at best, an ad hoc procedure, dependent upon local, state and federal monies. On the whole, however, science teachers have more training (advanced degrees and inservice education) than other teachers and are identified usually as leaders in their respective schools.

### Facilities and Equipment

Effective laboratory and field experiences require adequate science facilities, appropriately equipped for the investigative tasks to be done and with sufficient financial support for maintenance. (OSU 38, 39). In most school districts (64%) there is a budget for equipment and a budget for supplies (76%) (OSU 39). To maintain science laboratories in a satisfactory condition, school districts depend heavily upon the federal government for financial help (RTI 124; OSU 40-41). In 1970, on the average, local school districts budgeted \$3.00 per

student (OSU 37) and in 1975, \$5.50 per student (RTI 126) for supplies and equipment. Only 36% of junior high science teachers feel their facilities are adequate (RTI B:128). About one-fourth of science teachers and administrators consider inadequate facilities to be a major problem (RTI 159).

The teaching of biology can profit from special facilities, but few high schools possess them. Greenhouses and nature trails are available in 28% of the schools, land or outdoor labs in 17% and a ventilated animal house in 14% (ERIC 110-112). About 44% of the biology teachers either use or would like to have a greenhouse, but 50% of those teaching grades 10-12 see no need for one (RTI 131). In 1971, the schools having these special facilities made little use of them; for example, the percentage of teachers reporting that they make frequent use of a greenhouse was 31%, of nature trails 6%, of land labs 18%, and of the animal house 43% (ERIC 110-112). In 1977, only 15% of the teachers who have greenhouses available use them (RTI 130).

Equipment commonly used in teaching biology appears to be in adequate supply. Instructional models were found in 79% of the schools and were used ten days or more in 44% of the schools (RTI 127, B:87).

More than 80% of the students in the NAEP sample report having used a microscope to observe living organisms, and two-thirds have made a microscope slide (NAEP C09001). Ninety-eight percent of the students have had an opportunity to personally use a microscope and a magnifying glass before completing high school (NAEP C09001). Thirty-three percent of biology teachers do not see a need for microscopes and only 1% report they are needed but not available (RTI 131). Biological models have been used in 70% of grades 10-12 science classes for instruction (RTI 132).

Only 4% of the grades 10-12 science teachers report they do not have living plants available and 7% do not have live animals to use for the teaching of biology (RTI B:87). Living plants are reported to be used by only 6% of the schools at least ten days per year while living animals are used in 28% of the schools ten days or more per year in grades 10-12 science classes (RTI 120). Between 25% and 31% of teachers at each grade level report a need for help with maintaining live animals and plants for class use (RTI 149).

Regarding common equipment desirable in teaching science, between 86-99% of the schools (senior high schools) report they have what is needed (RTI B:87), but in nearly half of the high schools surveyed the materials are getting

out-of-date (RTI B:128) or becoming "run down" (CSSE 13:63). The current tight budgets in schools are seen as lowering the quality of instruction (CSSE 18:37-42, 97) and representing a serious problem (OSU 133; RTI B:128; CSSE 18:88-89). A particularly annoying financial problem reported by 47% of the grades 10-12 science teachers is the lack of funds to buy day-to-day materials as needed (RTI 135). Fifty-eight percent of the biology teachers reported needing laboratory assistants (RTI 134, 136).

Problems related to space in science facilities or their lack of flexibility is frequently cited by teachers as a problem. Specific problems cited by teachers relative to space needs are: (1) storage, 39%; (2) space for class preparation, 28%; and (3) space for small group activity, 44% (RTI 135, B:100).

#### Methodology

In biology teaching, methodology involves both the classroom and the laboratory. In this section, common teaching practices as are the laboratory materials presented by the three biology texts, Modern Biology, BSCS: An Inquiry into Life and BSCS: An Ecological Approach, which are used by 80% of all students (OSU 26). As previously mentioned, three conditions are most evident: the textbook is the basis of instruction (CSSE 19:6); the teacher determines the tone and the type of learning experience (CSSE 19:2); and lecture-discussion is the prevalent mode of presentation (RTI 101, 105).

Certain organizational patterns and classroom practices are prevalent. For example, the majority of schools have six to seven class periods of 45-60 minutes each; fewer than 10% of the schools have modular schedules (OSU 15). Science, including biology, is primarily taught by departments, and average class size has been reduced from over 30 in the 1950's to 24-25 in the 1970's (OSU 32). Within the classroom, the lecture is the primary mode of instruction; 55% of the teachers rank the lecture as the most important learning activity (ERIC 131) with 26% of science classes having daily lectures and 37% of them having at least weekly lectures (RTI 103). There is the pervasive practice of "assign, recite, test, discuss" in the elementary science classroom (CSSE 13:5). In the junior high schools recitation is the primary instructional mode (CSSE 19:6).

The basic classroom instructional resource is the textbook. Teachers rely on and believe in the text (CSSE 19:6). It is the "answer place" for teacher

questions (CSSE 13:62), almost all of which come from the text and concern terminology and definition (CSSE 19:6).

More than 90% of the 12,000 science teachers surveyed by EPIE said that texts were the heart of their teaching 90-95% of the time (CSSE 13:66). The textbook is both the medium and the message, and biology teachers, in general, do not stray far from its organization and content.

Fewer than half of the teachers use inquiry approaches (RTI 148; CSSE 8:13), and many believe that inquiry only "works" with bright youngsters from intellectually motivated families (CSSE 12:7). 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 (CSSE 15:4). Furthermore, "creative inquiry" was not found in any of the eleven school science laboratories involved in extensive case studies (CSSE 12:7).

Few students are exposed to individualized instruction (OSU 35), which is defined generally as self-pacing toward a common goal rather than developing individual experiences (CSSE B:26). Generally, individualized systems and programs are used as a supplement rather than a central mode of instruction (CSSE 16:55), and the offering of alternatives is usually seen as fulfilling parents', not students', needs (CSSE B:26). In addition, the 1976-1977 NAEP Survey of Attitudes Toward Science indicates an almost total lack of individualized or flexible instruction in the sciences. For example, fewer than 10% of the seventeen-year-old students have helped select the manner of learning, the sequence of topics, or the time of testing in their science classes (NAEP C01E06). However, black, urban disadvantaged students, at ages 13 and 17, have more involvement with determining the science instructional practices than students in general at those ages. This involvement may indicate more individualized instructional practices; for example, the percentage of black students who have worked at their own pace is eighteen percentage points higher than that of seventeen-year-old students in general. Likewise, over 7% more black seventeen-year-olds have chosen their own topics or projects, have elected the way they wanted to learn, have selected the sequence of topics in science, and have decided when to take tests (NAEP C01E06). All of these findings are indicative of individualized modes of instruction. The national concern with compensatory education for culturally and economically deprived minorities may have resulted in this pattern.

Although individualized materials and practices are not found in the schools, teachers are interested in them. One national survey indicates that 68%

of science teachers are "seriously" or "somewhat" concerned about using student-oriented, individually-paced programs and that 29% of them indicate that the lack of appropriate individualized materials ranks first among eighteen instructional problems (RTI 158).

A distinguishing feature of the biology curriculum reform movement of the 1960's has been the importance of laboratory and field experiences for students (OSU 38). One result is that many more "lab instruction" and "inquiry" activities were used in 1975 than previously (OSU 32). Even so, there are substantial numbers of teachers who do not emphasize laboratory work (OSU 32); learning by experience does not have a high priority in science teaching (CSSE 15:7). Nearly half the teachers feel they need more help in learning how to implement an inquiry, "hands-on" approach in the laboratory (RTI B:112-115; 147). When asked why they avoid experience-based curricula, science teachers' responses reflect two factors: first, the philosophically strong bias toward "book learning" and second, the frustration and difficulties experienced by teachers who tried (and are now rejecting) the experience-based curriculum (CSSE 15:6). Even proper training and the NSF-inservice institutes have not alleviated this frustration, for teachers do not have the time to "collect, organize, set up, take down, clean up, and store" the materials needed for hands-on activities (CSSE 15:7).

Forty-two percent of science teachers ranked group laboratory as the "most" or "next most" important learning activity. However, 20% of science teachers did not rank it at all (ERIC 131). The individual laboratory fared even more poorly as an important learning activity; 11% of science teachers ranked the individual laboratory as the most important activity, 17% as the next most important, 9% as third. However, 27% of the science teachers merely noted that they "used" individual labs, while 36% did not rank this activity (ERIC 132). Although 48% of science classes (grades 10-12) use manipulatives "once a week or more often", 9% of science classes never use manipulative materials, and another 14% use them less than once a month (RTI 107). However, teachers who have attended NSF institutes are more likely to use manipulative materials than others (RTI 107; OSU 32). Although 96% of science classes reported using demonstrations (RTI 110), only 15.8% of the teachers ranked them as the "most," or "next most," important learning activity (ERIC 132). There is also evidence of a diminishing use of living organisms as grade level increases (RTI 120).

There are many factors which weigh against the laboratory component of a science course. For example, "40% of the largest schools used non-science rooms for science instruction", and 25% of teachers report that they do not have laboratory facilities (OSU 88). Besides the facilities problems there is a general trend away from the laboratory component due to (1) lack of funds (CSSE 13:18, 61; 19:29; OSU 140, 148); (2) vandalism and discipline problems (CSSE 19:3, 13:18); (3) a move away from experience-based learning (CSSE 15:6); (4) pressure to cover textbook assignments (CSSE 13:63); (5) lack of time available "to set up and take down" equipment (CSSE 13:63); and (6) the common practice of not "showing" laboratory procedures on tests (CSSE 19:3). The lack of creative inquiry in biology teaching is undoubtedly influenced in part by these conditions (CSSE 12:7).

An examination of the three most commonly used textbooks shows that the number of laboratory activities available for use range from 63 to 70. Although not distributed evenly throughout these textbooks, the laboratory activities, if all were carried out, could account for 40% to 50% of the instructional time in any course. In each of the textbooks there is an attempt to achieve the "inquiry goal" by involving the student in carefully guided "investigations" or activities designed to develop competence in "processes" of science, such as careful observing, recording observations accurately and quantitatively, organizing and displaying information, hypothesizing and interpreting observations, and forming generalizations or conclusions. However, in practice, laboratory activities are frequently "cookbook" or "dissection" activities, and few are long-range. They pose a question which requires a finite, definite answer. New curriculum topics (ecology, behavior, etc.) seldom fit this pattern and therefore cause problems (CSSE 13:9). In varying degrees, the authors of the textbooks have sought to have laboratory experiences serve as a mode of learning biology as well as a way to develop an understanding of what is meant by scientific inquiry.

The laboratory activities described in Modern Biology differ from those included in the BSCS textbooks. For example, in Modern Biology emphasis on inquiry processes or scientific methods as an objective of the laboratory is limited. No more than ten of an estimated 300 inquiry objectives are related to an inquiry goal beyond that of direct observation. Laboratory activities usually involve students in processes such as organization, identification, and classification. Only infrequently is a student expected to extend an experimental activity; most activities represent ends in themselves. If the student is to extend the activity,

instruction is included in a section entitled "Investigation on Your Own." Furthermore, careers in science and/or biology are not mentioned, and social issues are not treated as investigative or decision-making activities.

Although guided inquiry is basically the format of the activities in the BSCS "Green" and "Yellow" versions, personal needs, careers, and societal issues are not included among the laboratory activities. In about one-third of the inquiries, students are required to formulate hypotheses; to predict outcomes; to design experiments; to develop observations and measurements procedures; to explain, transform and display results (in tables, graphs, or drawings); and to formulate generalizations. In 40% of the inquiries, students are required to express data in quantitative terms (e.g., relating movements to time or expressing percentages in genetics investigations). In about ten percent of the laboratory assignments, students are requested to design their own experiments.

In summary, the methodology used in biology is basically didactic with heavy reliance on the textbook as the source of information, with lecture-discussion as the mode of instruction. Furthermore, the teacher is the main determinant of both resources and instructional techniques. Teachers tend to ignore controversial issues in their classrooms (CSSE 12:29), and they encourage the qualities of a laboratory technician, rather than those of a great thinker in their students. That is, students are encouraged by instructional methodologies to develop the qualities of a trustworthy subordinate, one who is careful and productive (CSSE 12:27). "For essentially all of the science learned in school, the teacher is the enabler, the inspiration and the constraint." (CSSE 19:1).

#### Instructional Resources: Media

The primary instructional media in biology courses is the textbook (CSSE 19:6). Three biology books comprise 80% of the adopted textbooks: The Biological Sciences Curriculum Study textbooks ("Yellow" and "Green" versions) are used by 40% of the schools and Modern Biology (Holt, Rinehart, Winston) is used by 40% (OSU 26; RTI B:25). In about one-half of the classes a single textbook is used, and in 33% of the classes, more than one textbook are used (RTI 88, 89). There is some indication that teachers (who have the most to say about textbook adoptions) (RTI 99; CSSE 19:2) are increasingly inclined to reject the federally funded textbooks (CSSE 15:5; OSU 26). In 22% of the schools the science

textbook in use was published before 1971 (RTI 95). Of the various supplementary materials that go with a textbook, the teacher's manual is the most frequently used (RTI 97). Films and other audio-visual materials designed to accompany a specific textbook are used by no more than 25% of the teachers (RTI 97).

During the past two decades major efforts have been made to encourage science teachers to use a variety of media for instruction. However, the massive use of a variety of media has not been evidenced in practice (CSSE 8:13). The two instructional items most commonly used in biology classes are: (1) microscopes, used by 63% of the grades 10-12 teachers (one-third of the teachers report they are not needed, rather than not available); and (2) models, used by 70% of grades 10-12 science teachers (RTI 130, 132). In general, schools are better equipped for science instruction now than they were twenty years ago. This has been achieved through federal support in 50% of the schools (OSU 35).

About 80% of the science teachers use audio-visual materials for instruction at one time or another (RTI 112). The most frequently used audio-visual materials are the overhead projector, films and filmstrips (RTI 114). Films and filmstrips are used as often as once a week by 16% and 13% of the of the teachers respectively (RTI 112). Audio-visual equipment is widely available in schools with at least 90% of the schools reporting having motion picture projectors, overhead projectors, commercial charts, models, tape recorders and loopfilm projectors (ERIC 116-120). Microprojectors and television receivers are found in 70% of the schools (ERIC 172-173). One-fourth of the high schools have greenhouses and a smaller number (17%) has ventilated animal houses and weather stations (19%) (ERIC 110, 111, 113). In the schools having access to these various media, 50% or less "frequently" use them.

While 30% of the schools have facilities for closed circuit television, 70% of the teachers report they rarely or never make use of it (ERIC 109). More than 60% of the teachers feel no need for either standard or closed circuit television for instructional purposes (RTI 114). Educational television is regarded as promising but is little used (CSSE 13:52-53; RTI 116). Fewer than 10% of the schools report the use of television or computer-assisted instruction in any consistent manner (OSU 190); however, the percentage is increasing (OSU 32).

The study of living organisms in biology classes is limited; six percent of the grades 10-12 science teachers state they use live plants at least ten days of the school year, yet 28% use living animals equally as often (RTI 120).

While there is an increasing number of alternatives for instruction, there appears to be little effort invested in building these into an articulated system of instruction (OSU 190). Individualized systems and programs are viewed as supplementary to mainline courses (CSSE 16:55) and particular media are used largely as a means of providing another information source in addition to the textbook.

#### Instructional Resources: Out-of-School

Teachers make little use of out-of-school resources that could be useful in biology teaching such as museums, parks, arboretums, libraries, and aquariums (CSSE 13:49-50). In addition, guest speakers are never used in 54% of the science classes (RTI 103). The out-of-doors and the world of living things is available to all biology teachers for observation and field studies; ironically, however, 80% of the schools report they have no special facilities for environmental education (ERIC 81). Nearly 30% of the schools have nature trails which are rarely or never used by 72% of the teachers (ERIC 109). Land laboratories are available in 17% of the schools and frequently used by 18% of the teachers (ERIC 111).

Field trips are used at least once a month by 7% of the classes but are never used by 31% (RTI 103). Many teachers view field trips as almost logistically impossible (CSSE 13:49). Out-of-school, science-oriented educational resources appear to be untapped (CSSE 13:58).

Students do engage in some unrequired, out-of-school science activities; nearly half of the students read science articles in magazines and newspapers but only 30% read books on science or about scientists (NAEP C01X01). More than 60% of the students watch science programs on television (NAEP C01X01), but neither educational nor commercial television is utilized much by teachers (CSSE 13:52, 53). While 39% of the students talk about science topics to their friends, only 8% have attended a lecture on science (NAEP C01X01). About one-half of all seventeen-year-olds attended a lecture on science (NAEP C01X01). However, the NAEP Survey of Attitudes Toward Science indicates that blacks, students in urban, disadvantaged areas, and students in big cities have significantly more extra-curricular science experiences than those comprising the national average. For example, almost 17% more seventeen-year-old blacks than seventeen-year-olds in general reported that they have read books on science and have done non-required

science projects. Furthermore, significantly more black seventeen-year-olds report that they read science articles in magazines and go to science lectures (NAEP C01X03). Although the interpretation of these responses is incomplete, their consistency suggests a pattern in science education.

Although community resources are seldom used directly by teachers, more than 90% of the students of high school age have visited a zoo, beach, lake, forest, farm, museum, hospital, doctor's office, park, river, and the mountains; a lesser number (74%) have been to an ocean; 33% have seen a desert; and 32% have visited a laboratory where research is done (NAEP C09V01). A closer analysis, again, shows a different pattern for black students, who have significantly fewer opportunities to use community resources. For example, at age 17, 16% fewer blacks have visited a planetarium, 2% fewer have gone to a zoo and 5% fewer have toured a museum (NAEP C09U01). Nationally, only 7% of science students have gone on a school-sponsored overnight trip to an outdoor laboratory (NAEP C09D01).

Non-formal educational agencies such as the Scouts, YMCA and YWCA, 4-H clubs, and summer camps include in their programs biology-oriented activities such as agriculture, wilderness ecology, physiological fitness, and food and nutrition projects (CSSE 13:54-56). These agencies serve a science education function yet receive little recognition for their efforts. There is an absence of systematic arrangements for the sharing of science education responsibilities between the schools and the agencies outside of schools, even though such sharing might be mutually helpful to both types of agencies (CSSE 13:56-57).

### Student Characteristics

Although the three NSF status studies provide little direct information, other than student statements in the Case Studies, the NAEP data provide insights into student reactions to school biology programs (NAEP C09D01, C01E01). The data available for school "science" were gathered from thirteen-year-olds in junior high and from seventeen-year-olds in high school.

Science is the favorite subject (first and second choices) for 26% of the high school students, falling behind language arts selected by 33%, mathematics selected by 31%, and social studies selected by 29% (NAEP C01E01). Science classes are reported to be boring "always" or "often" by 31% of the high school students, "seldom" or "never" by 15%. In another study, one-third of the students polled reported science classes as "boring" and the subject matter as "irrelevant;"

many students reported that science is aimed at "bright" students (CSSE 18:107). A different situation is reported for junior high school students. At that level, 21% of these students report science as "often" or "always" boring, while 31% 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 (NAEP C01E02). Again, an analysis of the responses by race indicates that blacks, at age seventeen, found science less boring (27% black/17%white), found it more fun (30% black/26% white), and indicated more often that they liked to go to science classes (48% black/35% white) (NAEP C01E02).

Generally, students report that content of science is interesting: 45% report it so "often," while 16% report it so "seldom" (NAEP C01E01). Twenty-two percent of the students report science as "too difficult," while 6% report it to be "too easy." Fifty-five percent of the students characterize science as "always" or "often" consisting of facts to be memorized. It appears that one-half of the secondary students are not unhappy with science classes. More than one-half report that science often makes them curious. One-half also report that science classes seldom make them feel either confident or unhappy. About one-fourth of the students feel science makes them feel successful, while an equal number report that it does not (NAEP C01E04). Teachers report, however, that developing student motivation is a major problem (CSSE 15:23).

Students of high school age have had a wide range of biology-related experiences obtained either in or out of school (NAEP C09D01). Eighty percent or more of the students have taken their own temperature and pulse; collected flowers or leaves; taken care of plants and animals; observed the behavior of fish, bees, ants, birds; and have seen fossils and skeletons. At least 50% of the students have made a piece of science equipment, done an extended experiment, used a microscope by themselves, found a fossil, seen an animal being born or an egg hatch, or watched a seed sprout. However, at all ages, black students have had significantly fewer of these experiences. The common tools of biology such as scales, meter sticks, magnifying glasses, thermometers, microscopes and yard sticks have been used by over 90% of the students. Fewer students (57%) have used a stethoscope, and only 11% have used a pollution kit. Experiments with seeds, living plants, and chemicals have been conducted by approximately 80% of white students and 65% of black students (NAEP C09S01). Half of the students have done

experiments involving human behavior, erosion, living animals, and the sun as a source of energy.

About 45% of the students report they plan to take more than minimal science in high school, while 37% report that they do not (NAEP C01U01). About one-third of the students report they would like a career in science or in a science-related field, while an equal number responded negatively. Over 70% would like to see scientists at work, and even more (77%) 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% 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% feel scientific work would be lonely, 54% do not. Interestingly, black respondents were more positive (by approximately 25%) 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 (NAEP C02A03). However, more students feel that science cannot solve the problem of disease than those who 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 or riding bicycles, helping with litter pick-up, separating trash for recycling, using economy cars, using less heat in winter, and using returnable bottles. Again, a more detailed analysis indicates that 19% fewer blacks than whites are willing to use less electricity; 17% fewer are willing to walk or to ride bikes in order to conserve energy. These responses may be indicative of different attitudes, or they may simply be the result of fewer material resources.

When asked about problem-solving in daily life (outside of science classes) students report that they only infrequently perform experiments (NAEP C04A03). However, half or more 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 also report that they are able to, and indeed do, use the results of scientific research in their daily lives. (This "use" includes choosing foods, healthful living, selecting products, such as toothpaste, and deciding about smoking.) Conversely, half of the students report that they use the methods of science rarely in making decisions which affect their lives. Students are confident science can help

resolve problems of starvation, energy shortages, cures for diseases, prevention of birth defects, saving natural resources, and reducing air and water pollution. Students do not feel that science can help control weather or prevent wars (NAEP C05A01). In most instances, students support the expenditures of funds for a wide variety of scientific studies and investigations.

For the most part, students understand the function of theories in science, how scientists interact and how science progresses (NAEP C08A01). Students do feel that scientists should be allowed to investigate most topics. However, they also support exercising controls, especially in such areas as genetic engineering, cloning, biological warfare, human behavior, and other controversial societal issues (NAEP C06A01). Students support the use of scientific knowledge and have faith in the value of science for resolving world problems. The student view of science, scientists, and the limitations of both are more positive than the curricula, teaching practices, and other data would suggest.

### Evaluation

Evaluation activities may be subdivided into three categories: teacher-made, classroom tests; standardized achievement measures; and competency-based assessments. Considering the first category, the majority of teacher-time is spent in soliciting both oral and written feedback from students (CSSE 15:15). The NSF studies 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 (CSSE 15:12). Laboratory time is often neglected because the results of laboratory work do not "show" on tests (CSSE 19:3). Most tests used in biology are teacher-developed and teachers are committed to their own testing practices (CSSE 15:15). Thirty-percent of the teachers test their classes at least once a month, while 35% report weekly testing (RTI 103). Tests are seen as a way of knowing "how well" students are doing (CSSE 15:12).

Classroom tests are public manifestations of student understanding (CSSE 12:3). However, tests are rarely used to make instructional decisions (CSSE 15:21-22). 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, which are considered fixed, a part of the system and, therefore, unquestioned by teachers (CSSE 15:19).

The second category, standardized achievement tests, actually consists of two types of measures: those that compare a student's science achievement to

that of his/her peers (SAT, ACT, STEP, ITED) and those that survey the nation, reporting average achievement patterns. Only one-third of the school districts use standardized tests, such as the STEP and Iowa (ITED) tests of science in grades 7 through 12 (RTI 27). Therefore, standardized testing is not a major concern of teachers; their use of achievement tests is a school decision. Teachers report that the results of testing programs are not valid measures of their programs and are not indicative of local problems and/or curricula (CSSE 15:20). On the other hand, there is a general public concern for the relatively lower scores on college entrance exams (SAT and ACT). Accountability as a concept is "in;" almost all districts now have designated "evaluation officers" (CSSE 17:10). Student test scores on national (SAT, ACT, NAEP) tests have declined over the past several years, a fact often reported and widely known (OSU 114-115). In spite of declining test scores, it is important to note that student satisfaction and attitudes toward science have improved (OSU 116). Valid reasons have been advanced explaining the decline of test scores (OSU 115), yet it is still felt that something must be done to reverse the trend.

Concerns about accountability in education and competency-based science programs, the third category, have increased within the last decade (OSU 147). There is a relationship between these programs and the basics movement; and state departments of education are the foci of pressure for these programs (OSU 124). However, only 2% of the states have established basic science competency levels for graduation from high school, and only 13% are planning such procedures with implementation dates not yet determined (RTI 31-32). Furthermore, there is no information to suggest that employers want competency information (CSSE 14:34). To date, the minimum competency movement has had little impact on secondary science education (OSU 30).

The impact of evaluation, then, is on the classroom where testing is considered a basic part of the biology curriculum (CSSE 15:12). Teachers report that standardized tests have little influence on classroom procedure or programs. However, standardized science tests are used to provide feedback to individual teachers of grades 7-12 (77%) to furnish information for parents (51%), and to place students in remedial programs (48%) (RTI 29). Furthermore, competency-based assessment programs have not been established widely either in science or in biology. However, the following statement attests to the general impact of standardized and/or competency-based evaluation on science curriculum:

"In response to poor student performances on tests, to other embarrassments such as nationally publicized lawsuits brought by non-reading graduates, to a belief that technology could improve the efficiency of instruction, and to a perceived need for more control over the whole teaching-learning system, a nation-wide effort has been undertaken to make teaching more explicit and more rational and to make learning more uniform and more measurable. Evidence of this effort was apparent in all our sites and confirmed our national survey." (CSSE 19:10).

#### Student Outcomes: Personal Needs

One of the expected outcomes from a course in biology is that the student will recognize ways in which the acquired information can serve personal needs. By the time students are seventeen years old, approximately 90% recognize the dangers of insecticides (NAEP C71C05), know the symptoms of common illnesses (NAEP C71C06), recognize when one should consult a medical doctor (NAEP C71C01), know that beef and milk are rich in proteins (NAEP C71C02), can correctly interpret an advertisement for a proprietary medicine (NAEP C71C03), know common practices for saving natural resources (NAEP C71C08), and know when it is good practice to use an authority for biological information (NAEP C71C09). Furthermore, fifty percent of the students know what to do for a person choking on food (NAEP C61C02).

While students know a lot about diets, they are less successful in identifying foods rich or deficient in proteins except for beef and milk (NAEP C71C02). Students also have difficulty in interpreting the meaning of "relief" as distinguished from "cure" in reading advertisements for proprietary medicines (NAEP C71C03).

Seventeen-year-old students are better informed than thirteen-year-old students in all categories of information regarding personal needs. On the topics where seventeen-year-old students are weak, the thirteen-year-old students are proportionally deficient.

#### Student Outcomes: Societal Needs

There are a number of societal needs (problems and issues) that require a knowledge of biology for proper interpretation, understanding, and resolution. Students are well-informed (80-90% level) about the extent of venereal diseases (NAEP C61C05), reasons for the use of drugs (NAEP C61C06), the value of vaccines for controlling relevant diseases (NAEP C61C08), dangers of excessive noise on hearing (NAEP C62C13), reasons for worldwide water shortages (NAEP C63C03), and they recognize the need for a world view of the human population problem

(NAEP C63C17).

Students, generally, are less well informed (50-65%) about causes of death among young adults (NAEP C61C04), the concept of renewable resources (NAEP C62C02), the possible results of deforestation on flooding (NAEP C62C03), the interrelationship of water, energy, and population problems (NAEP C62C07), the variety of factors contributing to air pollution, and the relationship of food shortage and adequate protein in the diet (NAEP C63C08).

Problems related to food production and to the "green revolution" are not understood by two-thirds of students up to age seventeen (NAEP C63C04, C63C05). Only 3% of the seventeen-year-old students knew that the survival rate of babies under one year of age in the United States ranks between 10th and 20th of all national infant survival rates. Less than one-fourth of the students can identify a graphic representation of human population growth viewed over the past 1000 years (NAEP C63C01); the notion of exponential growth appears to be vague in the minds of most students (NAEP C46C01).

Problems and issues related to environmental pollution are recognized by about one-half of the students (NAEP C62C04, C62C08, C62C09, C62C12). However, a majority (60-70%) of students can correctly identify factors which effect change on an ecological system (NAEP C47C01, C42C03).

#### Student Outcomes: Scientific Knowledge

To provide an indication of the biology achievement levels of high school students as they approach graduation (age\*seventeen), results from the 1976-1977 National Assessment of Educational Progress (NAEP) - Science were used. The results of the biology assessment are classified by level of achievement for each of the major biological concepts sampled by the NAEP tests. The number of students tested in the seventeen-year-old category was 2,500. The level of achievement in the following list of biology concepts is the percentage of students who understand the concept.

Concept	Level of Achievement			NAEP Reference
	75-100%	50-74%	25-49%	
<u>Genetics</u>				
Recognize a dominant hereditary trait	68			C14C01
Know inheritance of sex is dependent upon father's chromosomes	77			C14C03

Concept	Level of Achievement			NAEP Reference
	75-100%	50-74%	25-49%	
<u>Genetics</u>				
Know mutations are changes in genes			32	C14C06
Recognize that pure strains can produce hybrids			41	C14C07
Know sperm and eggs have one-half the number of chromosomes for the species			47	C15C07
Recognize that when a plant cell divides each cell will have the same number of chromosomes		53		C12C02
Can distinguish a variety of hereditary and environmental factors on performance	90, 79	52	37	C14C05
<u>Diversity</u>				
Recognize people differ in "normal" body temperature			47	C13C07
<u>Cell Characteristics</u>				
Can distinguish nerve cells from other types of body cells	77			C12C01
Recognize a faulty statement about the function of cilia			63	C12C04
<u>Life Processes Common to Plants and Animals</u>				
Reproduction	90			C11C07
Use gases from air			74	
Need oxygen			63	
Sense environmental influences			76	
<u>Photosynthesis</u>				
Recognize that chlorophyll is a characteristic of plants	89			C11C07
Know that water, carbon dioxide, chlorophyll needed for photosynthesis			59	C13C01
<u>Behavior</u>				
Recognize that primates differ from frogs in responses to environment			39	C15C06
Identify territorial behavior	93			C18C01

Concept	Level of Achievement			NAEP Reference
	75-100%	50-74%	25-49%	
<u>Behavior</u>				
Recognize value of pecking order		50		C18C02
Recognize innate behavior:				
Bird migration	89			C18C05
Smiling	85			C18C04
Breathing			45	C18C04
Identify learned behaviors correctly:				
Swimming	98			C18C04
Handwriting	93			C18C04
<u>Environmental Pollution</u>				
Recognize danger of chemical sprays to people	77			C17C12
Recognize biological effects of hot water dumped into streams			40	C17C13
<u>Growth</u>				
Identify a seed as a source of food for growth			28	C19C05
Recognize that an egg and bean seed both store food		60		C19C13
<u>Ecosystems</u>				
Recognize relation of seasonal rainfall to the population of plant species		54		C17C01
Recognize conditions favorable to seed dispersal		66		C16C04
Identify environmental factors characteristic of sea turtles:				
Light		71		C17C07
Wind			43	
Other turtles	88			
Water	97			
Correctly interpret questions related to a food pyramid:				
A grass level		57		C17C06
Smallest population level		52		
Least amount of energy level			41	

Concept	Level of Achievement			NAEP Reference
	75-100%	50-74%	25-49%	
<u>Ecosystems</u>				
Correctly interpret questions related to a food pyramid:				
Level at which animals eat only plants			34	
Identify a balanced community	51			C16C03
<u>Classification</u>				
Identify pigs and people as mammals			27	C11C08
Recognize that chlorophyll is unique to plants	89			C11C07
<u>Experimental Design</u>				
Recognize appropriate units of measurement	82			C13C02
<u>Evolution</u>				
Recognize a survival of the fittest	52			C16C02
<u>Energetics</u>				
Recognize that growing plants produce more energy than they use			27	C13C04
Know that animals need oxygen and give off carbon dioxide	62			C15C02
Know that carbohydrates are a quick source of energy			34	C15C03
<u>Health and Disease</u>				
Know that diseases caused by bacteria may be prevented by:				
An unbroken skin	66			C10C02
Sufficient white blood cells	62			
Adequate diet			46	
Enough antibodies	71			
Avoiding direct contact with a person with a disease	77			
Know the value of throat swab to help identify the cause of a sore throat	87			C10C04
Can recognize a balanced diet	55			C10C03
Know that cigarette smoking is dangerous to one's health	99			C10C06

Student Outcomes: Career Education and Preparation

The whole question of career awareness and preparation is fraught with conflicts as to the nature of the goal, its appropriateness as a goal of science instruction, and the availability of suitable curriculum materials.

To what extent is the goal of career education accepted in schools?

Nearly two-thirds of the parents and 59% of school superintendents feel that science courses should be aimed (more than they are) toward vocational goals, but only 34% of the science supervisors (grades 7-12) agree. Science supervisors and school superintendents (63% each) feel that youth unemployment is more an economic problem than a curriculum problem, and half the parents agree (CSSE 18:43). Parents (79%) and school superintendents (72%) agree that youngsters should be taught, in school, how to get and hold a job, but only one-third (34%) of the science supervisors feel this way (CSSE 18:43). Science supervisors (78%) state that employers do expect a new worker to be ready for the responsibility of a new job; however, only 31% of the parents and 41% of the school superintendents take this position (CSSE 18:43). A majority of parents (76%), superintendents (66%), and science supervisors (79%) agree that a good general education is more desirable than vocational education if a choice has to be made (CSSE 18:44).

In a number of states, career education is listed in the top ten educational goals, priorities, or crucial issues (OSU 159-160). The fourth annual Gallup poll of attitudes toward education (1972) revealed that 44% of the public is of the opinion that one of the goals of schooling should be prepare students to get better jobs (OSU 160). By and large, parents see the responsibility for vocational preparation as more important than do school personnel (CSSE 17:21). Seventy-eight percent of the parents view the main responsibility of the schools to be the preparation of young people for their life's work; however, school administrators (81%), supervisors (66%), and teachers (71%) see this task as important but not the most important task of the school (CSSE 18:102); students are evenly divided in their opinion on the issue. Only a few parents, however, appear ready to sacrifice any of the scholastic program to get youngsters ready for jobs; they do not see this as a trade-off (CSSE 17:21). However, both students and parents rate the career purpose of education above that of knowledge and human goals (CSSE 18:103). When parents think of education for the future it is most often thought of in terms of a working career and not in terms of the future of the social order (CSSE 17:21).

Career counselling in schools is viewed as inadequate especially by students who plan to enter the job market upon graduation (CSSE 12:25a). School counselors indicate that more of their counselling activities are associated with academic and personal matters than with vocational matters (CSSE 18:25). Approximately 40% of the students and their parents agree, however, that the career purpose of education is receiving considerable emphasis in their schools (CSSE 18:104); but a review of public documents and of educational literature reveals that there is an increasing general concern about career education in the schools and the need to develop vocational skills (OSU 147). Part of the problem is related to the inability of the school to offer much more than more schooling as career preparation rather than actual field experiences in jobs (CSSE B:26). When students in the senior class were asked about their plans following graduation from high school, only 20% thought they would be working, 71% planned to attend college, and 5% were considering entering a vocational school (CSSE 18:26). Work is central to the thinking of American youth at the precollege level of education (CSSE B:23). Work means money and what money can buy. However, jobs for youth are difficult to obtain, especially for blacks, and where they exist they represent only an immediate career choice (CSSE B:23-24). Long-range career choices are hampered by educational, economic, and political conditions beyond the control of schools and individuals (CSSE B:24-26).

Providing a strong program for those students who will become the nation's future scientists is not found to be a high priority in school systems (CSSE 12:1). Occasionally students are counseled into careers in the sciences. For the most part, counselors see their primary responsibility as placing students in tracks; they have heavy counselling loads and seldom have time for long-range career planning (CSSE 12:25a). There are efforts, as early as in the junior high school years, to segregate students into courses for the "better achievers" and for "slow learners;" the "better" track leads to college and one may presume an opportunity to major in a science (CSSE 12:22). Although there is some resistance in schools to the idea that science instruction should be preparation for work, science is taught in terms of facts and skills that are vocationally oriented (CSSE 12:22). While sex differences in selecting science courses have been observed in schools, efforts to increase female enrollment are having positive results (CSSE 12:24; 15:34-38); thus, girls should not be at a disadvantage should they later decide on a science career.

Seventeen-year-old students do show an interest in science careers as revealed by their responses to the following questions: (1) "Would you like to work on a job that allows you to use science?" -- 39% indicated "yes" and 35% "no;" (2) "Would you like to visit a scientist at work?" -- 71% said "yes" and 16% "no;" (NAEP A01818); (3) "Are there science-related jobs you would like to do?" -- 77% said "yes" and 9% "no;" (4) "Would you like to know more about jobs in science and engineering?" -- over 50% of the students indicated that they would, while 39% indicated they would not (NAEP A01818); (5) "Would you like to work in a laboratory?" -- "Yes" was the response of 43% of the students, while 36% said "no" (NAEP A02818); (6) "Do you think working in a science-related field would be boring?" -- 46% of seventeen-year-olds think scientific work would not be boring, but 31% think it would be.

Science supervisors and parents tend to disagree about the extent to which career education is a responsibility of the science teacher (CSSE 18:43-44). Part of the disagreement may stem from the fact there is not a standard interpretation of "career education." There is general agreement (37% to 52%) among school administrators, science supervisors, students, and parents that one of the most important uses of federal government funds supporting science teaching should be to develop science courses oriented to present and future job markets (CSSE 18:100). In addition, teachers, especially junior high school teachers, need special preparation if they are to help their pupils become aware of the variety of careers in science (OSU 71). A survey of high school counselors revealed that only 10% had at one time taught science or mathematics (CSSE 18:25).

The widespread public interest in career education is not found with equal enthusiasm in the schools. The concept of career education, introduced in 1971 by Sidney P. Marland, the U. S. Commissioner of Education, does not seem to have impressed, or perhaps is not understood by, science teachers and science supervisors. Part of the problem is a failure to relate academic and career goals in a meaningful way. Career awareness activities are not written into the most widely used science textbooks in the junior and senior high schools. Thus, career information is neglected, even though the majority of students would like more career-related activities (NAEP C02A01, C02A02). By the age of seventeen years, 80% of students have some idea of career demands, should they choose to become a biologist (NAEP C71C10).

Summary of Goal Cluster Outcomes

The inquiry goal is espoused but not practiced by biology teachers. A biology education designed to help understand and fulfill personal needs is generally perceived as unimportant. When it is addressed, it is often related to other goals such as careers. Interest in the societal needs goal is increasing; evidence for this is the fact that there are more courses such as environmental studies and ecology. Knowledge as discrete information has been and is the dominating goal of biology education. Though there is a recent interest in science career education, there is confusion about the meaning of the goal and also doubt as to the responsibility of biology teachers in achieving this goal.

CHAPTER 4

PHASE III BIOLOGY REPORT:

DISCREPANCIES, INFORMATION GAPS  
NEEDED RESEARCH AND RECOMMENDED SOLUTIONS

Biology Focus Group Members:

Paul DeHart Hurd, Chairman  
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Jane Butler Kahle  
Robert E. Yager

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## Introduction

To better illustrate the present status of biology teaching, the Phase III Report contrasts actual biology programs with a desired one. The description of actual biology curriculum and instruction was based on information presented in three complementary studies of the status of pre-college science education prepared for the National Science Foundation. Supplementary information was derived from reports of the National Assessment of Educational Progress (NAEP), the summary of research on biology teaching published by the Biological Sciences Curriculum Study and an analysis of the most widely used biology textbooks. (See Phase II Biology Report for citations of references used.)

The desired course (see Phase I Biology Report) was based on four considerations: (1) changing perspectives of science as an enterprise; (2) emerging transitions in the biological sciences, especially in the nature of the discipline and the current contexts in which biological knowledge is being portrayed; (3) shifts in the cultural/social scene, particularly in areas that have biological relevance; and (4) recent research on the teaching and learning of biology. Major concepts of biology (for example, behavior, form and function, genetics, energetics, evolution, etc.) were examined to identify ways in which the teaching of these concepts might be influenced to be consistent with the findings of our preliminary study of science, biology, and social trends. Biological evolution, for example, studied in the context of cultural change, is a view of evolution different in concept from that presented in textbooks used in actual biology courses. Biological knowledge, selected for its potential usefulness in the life and living of human beings, results in a curriculum that has few conceptual overlaps with conventional biology courses. The curriculum designed to accommodate the many transitions in science and society within the context of modern biology provides a basis for assessing the current status of biology teaching in the American schools.

The Phase III Biology Report is presented in four sections:

- I. Discrepancies is a description of differences in theory and practice between the actual and desired teaching of biology.
- II. Information gaps is an identification of areas in which additional data could provide a more complete description of the current status of biology teaching. Most of the information needed could be obtained by survey techniques.

- III. Needed research is an identification of critical areas and problems in biological education about which more reliable knowledge is needed. Normative/theoretical, developmental, and empirical research needs are described.
- IV. Recommended solutions is an exploration of strategies, tactics and procedures for the resolution of problems related to biological education.

The four sections of the Phase III Biology Report identify perspectives and directions for "next steps" in biology education. The suggestions, although the products of serious study and research, are not intended to be definitive but do provide a rational basis for dialogue and further research.

## Discrepancies

### The Conceptual Framework for the Desired Biology Program

A major discrepancy between the actual and desired biology programs is found in the philosophical and 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. The subject matter of courses is selected for the potential it holds for improving the adaptive capacity of individuals and for advancing the welfare of humankind in general. The actual biology course is designed to portray the structure of biological disciplines and to provide experience in the investigative modes of these disciplines.

A major 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 essentially portrays 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 human progress toward future conditions that are likely to improve the quality of human existence.

Increasingly, science as an enterprise is becoming even more significant in setting the course of society. 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. More of an effort is made in the desired course to have what is learned directly serve the student as an end in itself, that is, to increase the adaptive range of the individual as a person and as a member of the social group. Biology taught in this mode has direct relevance and significance for every student; this position contrasts with knowing for the sake of knowing but does not minimize the actual importance of biological knowledge. Current biology teaching tends to reflect a reductionist point-of-view; whereas, in the desired state the emphasis is more on a holistic-ecological orientation.

The desired biology program is more interdisciplinary in scope; subject

matter is selected from many human sciences, such as human ecology, human genetics, cultural and physical anthropology, environmental psychology, socio-biology, and other fields. The typical biology course tends to be bound to a limited range of the classical biological disciplines, slighting the newer 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 biology as a discipline, and with contemporary conditions in society and in the culture. A summary of the discrepancies between the desired and actual states of biology teaching resulting from contrasting philosophical positions is present in Table I.

TABLE I

DISCREPANCIES: A SUMMARY

<u>Desired Program</u>	<u>Actual Program</u>
<u>Goals:</u>	
1. Human adaptation emphasized.	1. Minimal consideration given to human adaptive capacities.
2. Social problems and issues as goals.	2. Marginal emphasis on social 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 bio-social contexts.	4. Discovering a correct answer for a discipline-bound problem.
5. Career awareness an integral part of learning.	5. Minimal attention to careers, mostly of historical importance only.
6. Value, ethical, and moral considerations of bio-social problems and issues.	6. Value-free interpretations of discipline-bound problems.
<u>Curriculum:</u>	
7. Curriculum as problem-centered flexible, and culturally as well as biologically valid.	7. Curriculum is textbook-centered inflexible; only biological validity considered.

- |  |   |
|--|---|
| 8. Humankind central.  | 8. Humankind incidental.  |
| 9. Multi-ceted, including local and community relevance.   | 9. Textbook controlled, local relevance fortuitous.   |
| 10. Greater 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 specimens as a focus 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.  | 12. Group instruction geared for the average student and directed by the organization of the textbook. |
| 13. Cooperative work on problems and 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 science; behavioristic orientation.                |

Evaluation:

- |  |  |
|--|--|
| 15. Testing and evaluation reflects the use of knowledge to interpret personal/social problems and issues      | 15. Replication of assigned information.                 |
| 16. Student evaluation is based on growth in rational decision-making concerning personal and social problems. | 16. Stating "correct" solutions to pre-planned problems. |

Teachers:

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

19. Continuous professional growth is essential to maintain a valid curriculum and appropriate teaching practices.
19. Curriculum and teaching practices tend to be static.

Table I is a condensation of the major differences between the desired state of biology teaching and the actual state; these discrepancies are explored in more detail in the following sections of this report.

### Goals

The desired goals of biological education are perceived to be: (1) scientific literacy (knowledge); (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 intellectual processes are actually a part of biology teaching, the emphasis is upon selected skills of inquiry such as, observing, measuring and classifying. Rarely is the process of biological inquiry dealt with; only discrete inquiry skills are taught. In addition to the process of inquiry, the desired teaching of biology includes the art, habits and skills associated with the utilization of knowledge. Not only is current inquiry teaching not very successful and limited in effort, it appears to place almost no emphasis on decision-making skills 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. With the recent socialization of science, the teaching of biology, to be consistent with the "new science" (the desired state), must of necessity deal with values, morals, and ethics. In the past decade bioethics has become a new biology discipline.

The basic discrepancies between the knowledge goal as it is found in actual biology courses and 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 are 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.

Although the objectives and goals in the area of societal issues are heralded in science education writings as major justifications for biology education, such goals have not affected the typical discipline-oriented course in tenth grade biology. Biology goal statements may be responsive to problems and expectations of society in theory, but they appear not to influence the actual biology course. If societal issues related to biology are considered more than incidentally, they are usually treated in specially designed courses such as environmental studies or ecology. These courses, although increasing in enrollments, still serve a very small fraction of the student population.

Career education, as the development of students' career awareness, does not exist as a major goal of actual biology teaching. One does find in commonly used biology textbooks short biographies of well-known biologists who have made a substantial contribution to the development of biology. Recent editions of high school biology textbooks include pictures and achievements of modern biologists (Salk, Watson, Crick, Calvin, Krebs). Most of the scientists pictured are researchers; little attention is given to support staffs such as laboratory technicians, instrument developers, applied scientists, caretakers of live animals, museum directors, or para-professionals. In the desired biology program, the development of career awareness is a part of on-going instruction on every topic.

Biology teachers are inclined to think that providing career information to students is the task of the school counselors. Counselors feel overloaded with large numbers of students and see their primary responsibility as dealing with problems of personal adjustment (scholastic, social, personal, health) and with emergencies such as acts of vandalism, absenteeism, sudden illness, family emergencies and personal conflicts between students and teachers. They feel there is simply not enough time to talk about and plan career activities for individual students. Furthermore, it is doubtful they have essential

science career information, insights and competence since the great majority of counselors are trained in social studies or psychology.

### Curriculum

Early in the 1970's a number of societal problems and issues emerged which have a basic component in biology; these problems include environmental management, human population, worldwide health and food problems, quality of life, problems of human adaptability, etc. From these and other human conditions, holistic views of biology began to emerge for dealing with these comprehensive and interacting bio-social problems which have a personal as well as a social aspect, thus providing a new context for the teaching of biology. These conditions also establish the need to consider cultural validity in any refinements of a biology curriculum. The actual teaching of biology in schools has been only minimally responsive to these social and cultural shifts.

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 this knowledge is taught: from a discipline orientation to one of a personal-social living, and of a real-world 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 resolve personal and social problems of human adaptability.

The biology curriculum in the actual state represents a body of information to be acquired, whereas in the desired state knowledge is viewed as a social invention leading to biological and scientific enlightenment. The desired biology curriculum is more holistic in view and substance than traditional courses. The actual state of biology instruction is discipline-constrained, while the desired program is interdisciplinary in character, involving not only the natural sciences but also social and humanistic studies.

There appear to have been few efforts, with the exception of environmental courses, to establish a cultural validity to biology curricula reflecting prevailing social currents and cultural patterns. The desired course in biology

represents an effort to establish both a scientific and a cultural validity for what is to be taught. In the actual biology curriculum scientific validity is apparent; cultural validity is neglected.

### Instruction

A major difference between the actual and desired states of biology teaching is the context in which biological concepts and principles are studied. In the desired course the context of biological knowledge includes implications, intended to develop a higher level of student motivation, and more communicability than in traditional biology courses. The desired state of biological education is centered upon the human being as the "type" animal rather than upon the sub-human animal characteristic of actual courses.

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 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 environment. The teacher serves to facilitate this interaction. Learning, in conventional biology teaching, is viewed as a process of reception, retention, and recall of verbally coded information. The desired state of biology views learning as information processing and concept development.

The desired state of biology teaching stresses individualized and personalized (to develop self-responsibility) instruction for some goals (intellectual habits) and group learning for other goals (value, ethical, and bio-social problems). In the actual biology program, there is confusion about the pedagogical meaning of these styles of learning; individualized learning is interpreted as isolated and group learning as uniform. While teachers in actual courses tend to recognize that each individual is unique in interests, background and ability, only the class is taught, not the individual.

When biological knowledge is used outside of the discipline in which it was generated (the desired state) and for purposes other than the seeking of new knowledge, it functions to provide people with a basis for making more reliable decisions about problems and issues. Thus, the desired course in biology emphasizes

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. By attending to both kinds of skills, the teacher is able to depict the interaction of science and technology which are complementary endeavors.

In the actual state of biology teaching, problem-solving is viewed as a linear process proceeding stepwise from problem identification to a conclusion. In the desired state of biology teaching, attacking a problem is viewed as a systemic process which is not likely to be orderly or to result in a uniform answer.

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. Although the three major biology textbooks in actual use each contain approximately two laboratory activities per chapter, few teachers systematically utilize this much laboratory work. In actual biology teaching, laboratory activities are for the most part contrived routines, pre-programmed and with specified answers. The laboratory experiments are classroom-bound, bench-based, and mostly restricted to non-living specimens.

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 a social issue. The student is nearly always a part of the problem or involved in an indirect way as a member of a population. Investigations of this type are different from conventional biology investigations in that they frequently: 1) are multi-causal; 2) cannot be replicated; 3) do not have a single answer; 4) have results that may rest as much on a value judgment as the processing of data, and 5) may require a variety of investigative approaches to study. Typically, students work with problems that may be resolved but seldom solved, such as environmental, health, food, and quality-of-life problems.

It is suggested that in the desired state of biology the concept of "the laboratory" be reconceptualized. For example, examination of the bio-social problems associated with the desired biology program may not always be examined appropriately in a physical facility called "a laboratory". In the desired biology program, laboratory activities are in natural settings (the "real world" and are field-based or community-oriented.

In the actual state of biology teaching laboratory activities are confined

rather than open-ended; they are concerned with identifying or verifying facts rather than with societal or personal implications of the facts; they deal with short-term (one class period) rather than long-range study; the typical problem addresses a single variable rather than dealing with several variables and their interactions. In the actual biology program, laboratory experiments are generally designed upon a traditional (19th century) concept of scientific inquiry--problem identification, variable control, fact collection, forming hypotheses, data interpretation and conclusion. In the desired biology program laboratory procedures are more systemic in nature, less conclusion-directed and more decision-oriented. The statement of the problem may be the outcome of the investigation in the desired biology course.

In the desired program, laboratory activities are viewed as a confrontation between student(s) and real-world situations. The ideal investigation involves students with: (1) an interpretation, (2) a decision, (3) an action, (4) a related question, (5) an application, and (6) internalizing a biological concept. By extending the laboratory into the community and the adult world, students become aware of career opportunities. For example, a health-related problem may introduce students to a variety of health care careers such as physician, physical therapist, hospital manager, dietician, psychiatric nurse, and paramedic professions. Ideally, it will bring students into contact with practitioners in such careers.

In the desired biology course, personally and societally relevant problems are examined by various means, for example, opinion polls, demographic surveys, statistical analyses, literature reviews, museum trips, personal study, and laboratory experiments. Techniques of investigation may also be borrowed from the social sciences (sociology, anthropology, psychology, economics, geography, political science). Problems are examined both from methodological and conceptual viewpoints. Frequently, students investigate problems and issues prior to their formal introduction as part of class instruction.

The desired biology laboratory program may be summarized in terms of the following attributes:

1. Activities have a long-term view for at least half of the problems.
2. Activities originate as problems, that is, as actual questions for which an answer is not presently known.

3. Activities are related to personal problems or to social issues at least half of the time.
4. At least half the investigations involve the student in studies of human beings.
5. A balance of cognitive, ethical, aesthetic and creative development is a result of the investigation.
6. Methodologies used are not only those traditionally associated with biological investigations, but also those which may be used in other disciplines dealing with the study of humans, e.g., psychology, sociology, and anthropology.
7. Activities involve a perceptual orientation (a) from present to future, and (b) from the individual to the community.
8. A contextual analysis of data is used.
9. Investigations which present long-term and over-all views of scientific inquiry are recommended.
10. Activities develop some awareness of careers as they relate to problems investigated.

The attributes of the desired biology laboratory program are in contrast to the actual course in which laboratory activities tend to have the following characteristics:

1. Generally, a short-term view of a problem is endorsed; i.e., the problem is to be solved in 1 to 2 class periods.
2. The "problem" is related to the textbook, and the solution verifies fact or condition integral to the discipline.
3. Social issues have only a marginal representation among all laboratory activities.
4. The organisms studied are phyla lower than mammals.
5. There is little application of the concepts developed in the laboratory to the interpretation of human beings as a biological species or to human beings as social organisms.

### 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 learned. In the desired program more attention is given to having students express their line of reasoning in resolving a problem, suggesting a program of action, interpreting

a situation and in other ways demonstrating their capability for logical 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. In the desired program this assumption is not made and students are called upon to demonstrate their ability to use what they have learned in model situations. The testing may involve a written or oral test, an action, a debate, a critical essay, and other means.

### The Teacher

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 biology course who view their function as a conveyor of knowledge and measure their success by scores their students make on standardized achievement tests.

The major difference between teachers of the desired and actual biology programs is a philosophical one. In the actual biology program the teachers' major commitment is to the students' cognitive development. In the desired program the emphasis is upon the student as a functioning and contributing member of society.

To achieve the goals of the desired program will require a program of inservice education that focuses more on the normative and conceptual framework for the teaching of biology and upon the meaning and nature of learning. This approach is in contrast to traditional inservice programs, where the emphasis is almost exclusively on updating subject matter, new instructional techniques, and teaching hardware.

## Information Gaps

### Introduction

The purpose of this second section of the Phase III Biology Report is to list some of the kinds of information we felt would have been useful to our task, but which were not included in the data base. Specific recommendations for research we included in the third section "Needed Research."

The three NSF status studies and the NAEP science data have provided much valuable information for describing and characterizing the actual state of biological education in the United States in 1978. However, some essential data are regrettably missing, making a synthesis of the information and a comparison of a desired state of biological education with the actual state less complete than expected. Prompt follow-up studies should be conducted to fill these gaps and to assure full benefit and use of the initial three status studies. Such action may be viewed as extensions of the 1978 efforts intended to: (1) provide full analyses of discrepancies between the ideal and actual states of biological education, (2) identify possible solutions for reducing discrepancies, and (3) determine future needs.

In identifying the gaps in available information the biology focus group organized its investigation according to the "critical elements" sequence identified by the Project Synthesis staff. These elements include: (1) goals of biological education; (2) students of secondary school biology; (3) biology programs; (4) biology teachers and (5) evaluation.

In addition to the need for more direct information on biology teaching there is a need to bring together relevant research information from other related fields of study. Three categories of information are needed to permit a full analysis of discrepancies between desired and actual states and to make recommendations for corrective actions and additional research. These cognate fields include: (1) pedagogical studies (involving learning, cognitive development, value and ethical information futures); (2) contemporary trends and thrusts in the science of biology (including bioethics, recombinant DNA, environmental research, holistic views); (3) science indicators (including enterprise, social indicators for trends, sociology and philosophy of science, and technology for the context of science.)

Furthermore, the NSF science status studies reveal that science in the secondary school is typically taught within the framework of a physical science model characteristic of the 19th-century science. Unfortunately, this includes the teaching of biology. This model of science is inappropriate for the teaching of modern biology. No information is available concerning the way teachers view the conceptual framework of biology as a whole and as a human science in particular. Such additional information would provide a more complete setting and a more accurate framework for assessing the status of biological education and for identifying specific needs in establishing future directions.

### Goals of Biological Education

A primary goal for much of secondary school biology teaching is to prepare students for college. What is not known is the specific subject matter expectations of colleges and universities for a background in biology as it related directly to success in college either as a biology major or as a liberal arts student. Nor is there information concerning the utility of specific biological principles for other study, work, or adult living.

Reported information concerning goals is very general. In addition, teacher and student goals and objectives pertaining to personal needs and societal issues are particularly limited. For this reason, it is impossible to assess teacher and student views as to the relative importance and the degree of achievement of goals. Reports that goals are in transition are not validated or exemplified. Furthermore, there is no differentiation of goals according to grade level, areas of science, or course focus (i.e., college preparation, general education, technological, career focus).

Although career awareness is included as a goal, information concerning this goal is limited in the status studies. What is occurring in schools in terms of biology programs, what the results of such programs are in terms of student outcomes, and what specific teachers are doing remain in question. Information regarding specific careers related to biology, training opportunities, and opportunities for special studies is limited. Although there are suggestions that few biology teachers feel a major responsibility to their students in the area of career awareness, the importance of this goal to students and parents is documented. More information in this area would be helpful in assessing the current status more accurately.

### Students in Secondary School Biology

Too little has been reported about student outcomes that result from students' experience with a given biology course. Information is limited concerning the nature of students who elect biology at various grade levels, the nature of specific courses, and the value of school experiences to future science courses and/or future adult work. Information on achievement and other outcomes for students who completed biology through the use of one of the basic texts (i.e., Modern Biology) or through one of the newer special courses (i.e., oceanography, environmental studies, integrated science, ecology) is not available.

Information is not available concerning student outcomes in biology when taught by teachers with various characteristics related to preparation, philosophy and belief systems, cognitive style, and attitude with materials (curriculum) held constant. Little attention has been directed to out-of-school experiences and their effect upon biological education. The effects of teacher, curriculum, and community experiences upon student learning, choice of courses, and attitude toward biology were not adequately addressed and constitute gaps in the information base.

There is a paucity of information about the universal interests of students in biological topics. Intuitively it is felt that the desired state of biology is closer to these interests than the actual state of biology teaching. It would be a simple matter to gather such information.

At every grade level from the elementary school through high school, teachers decry the inability of students to read biological materials. The persistence of reading problems from grade three on suggests that, for unknown reasons, the problem is not being resolved. The effect of reading ability upon success, attitudes, and learning in biology has not been adequately considered. The necessity for reading skills for the study of biology and/or the affect the study of biology can have upon reading skills is not clear.

Information from the NSF studies regarding student perceptions of assignments, questioning strategies, laboratory investigations and examinations is limited. The NAEP data (for science as a general field) suggests some interesting possibilities for biology teachers, curriculum developers, and interpreters of achievement information. Specific information concerning students, teachers,

programs, and schools was not reported in the 1978 status studies.

### Biology Programs

It is not entirely clear from the NSF science education status studies to what degree the educational problems that pertain to pre-college science education in general are problems for biology teaching specifically. Questions designed to provide these answers were not addressed by these studies. In addition, the analytical and normative frameworks for systematically describing the state of biological education and associated infrastructures are only incompletely dealt with in the NSF science status studies.

Little information was sought, and therefore little is available regarding the integration of biology with "science" throughout the 7-12 sequence. Interdisciplinary or trans-disciplinary approaches were not noted specifically. The effects of integrating science with major ideas in social studies and/or the humanities were not adequately investigated.

The attention given specific "new" courses in biological science was minimal. Although such courses (when considered collectively) involved substantial numbers of students, these courses and the students enrolled in them tended to be lost in miscellaneous categories. Since many of these offerings represent attempts to achieve the "desired state", this failure to collect more careful information is particularly disappointing. Information concerning the courses, goals, students, student learnings, teachers involved would be particularly desirable to analyze.

In a similar way, the use of such special supplementary materials in biology (i.e., OBIS, HSP modules, National Wildlife and Dairy Council materials, and others) was not adequately noted. A close look at curriculum, students, and teachers would be of interest as indicators of new directions. A look at test-center situations where HSP, ISIS, OBIS, USMES, and other new materials are in use would provide reliable information regarding direction and relative effectiveness of newer approaches in biological education.

The NSF status studies report concerns parents have about schools and schooling (discipline, costs, "basics") but do not identify their perspectives and priorities for a general education in the biological sciences for contemporary times. Information regarding use of community action projects in biology would have been useful information. Such projects as those

designed to control pollution at the community level, to monitor environmental factors, to improve energy conservation practices, to study safety hazards, and to participate in career awareness projects suggest a movement to the desired state in biology education. Unfortunately, specific information is unavailable about such instruction.

The information reported as missing, or labeled as "no response" for sizable numbers of teachers, indicates another kind of concern. Such lack of response on the part of teachers regarding instructional practices, such as the use of field trips, probably suggests that such strategies are not used. However, more precise information from a total sample would be desirable.

Of great interest would be the identification of quality programs, classrooms and teachers. Established criteria for "good" biology instruction and a special look at those programs meeting those criteria would be helpful as one considers the direction for biology education and for analysis of the discrepancies between desired and actual states. Examples of existing school programs which approximate the desired biology program would be helpful. Information as to how such programs were developed, implemented and staffed would be especially valuable.

Information concerning modules, units, texts, activities and other curricular components would be useful. Much of the information regarding materials as well as programs and teachers was lost to the "averages" reported in the NSF studies. Information concerning futures, new directions in biology, and new materials for collegiate programs would be useful. Knowledge of the degree of familiarity with such information of secondary school biology teachers would be useful.

Additional information regarding use of decision-making strategies, quality use of the laboratory, definition of such terms as problem solving, inquiry, and process would have been helpful. Again, much information and its interpretation has been lost in the 1978 studies.

More precise information would be valuable concerning biology and specific schools and teachers. Again, the information would be helpful in determining more accurately specific discrepancies between the desired and actual states. Areas of interest include cooperative problem solving, exemplary use of the natural environment, decision-making strategies involving biological issues, facilities, and procedures for encouraging individualized/personalized instruction, use of human resources in the community, and activities which require values and ethical choices.

The NSF status studies report that biology teachers could "do better" if

they were given "more support", but it is not clear what the nature of this support should be beyond that of more money. Improvements in curricula are generally more a matter of rationale and scholarship than finances. More precise information regarding the meaning of "more support" is needed.

In general, there are information gaps in the NSF studies regarding the biology programs because the investigators generalized to "science", were content with reporting the general situation, did not consider criteria for quality programs, and did not appear to consider the nature of information necessary for taking new directions in science education. There was a lack of a general framework for describing science education in general and biological education in particular. Little was done to examine the relative effectiveness of goals, programs, or teaching. Little attention was given to out-of-school learning, parental and community influences, and public literacy in biology or in science in general.

#### Teachers in Biology

Little seems to be known about educational beliefs of biology teachers, their concepts of science and technology, the meaning they attach to scientific literacy, and the philosophical assumptions that guide their teaching endeavors. The NSF studies do not investigate teacher belief systems and/or their understanding of the framework of biology. The rationale for the use of given materials, procedures, and organization for biology instruction in secondary schools has been largely ignored.

Nowhere in the NSF science education status studies is information reported concerning the criteria teachers use in selecting and using given instructional practices for the teaching of biology. The reasons a teacher selects a certain biology curriculum (textbook) is not known, nor, and more importantly, why programs and practices are discarded. Why teachers use, or do not use, library resources, specific questioning strategies, community resources, individual assignments, or various forms of media is unknown. Such reasons perhaps would represent information at least as valuable as the information concerning use or non-use.

Additional information regarding the nature of biology teachers who are involved with team teaching, out-of-school activities, exemplary use of the natural environment, and decision-making strategies would be desirable.

More precise information regarding participation of biology teachers in

professional organizations (i.e., annual meetings, contributions to periodicals, work on committees, etc.) would be useful. Information concerning the reading habits of biology teachers as well as a more careful analysis of the mechanism of their learning about new programs, directions and activities are needed. Information concerning the effectiveness of support systems (supervisors, administrators, department chairpersons) is needed. As with programs, information concerning superior teachers would be of value. What happens when a teacher rarely uses a textbook? What kinds of out-of-school contacts does a quality teacher provide? How does the effective teacher interface with parents, administrators and coordinators? What factors have stimulated teacher change? How have some teachers made their philosophies more consistent with teacher practices?

Another general concern related to the biology teacher is the nature of teacher education programs. It is suspected that perhaps as many as 40 percent of those teaching biology or life science courses do not have a teaching major in the subject; a study of biology teachers' qualifications and assignment is needed. The information provided by the NSF studies is too global and inadequate for analyzing courses and the meaning of certain discrepancies between the desired and actual states of biology education in secondary schools. Analyses of teacher behavior, philosophy, and effectiveness based upon information other than total credit hours in biology or the number of NSF institutes attended would be helpful. Again, the nature of the preservice programs and that of the inservice experiences needs study and analysis. Information regarding the features of effective preservice and inservice programs is needed.

#### Evaluation of Biology Education

Since evaluation is frequently equated with testing, it is not surprising that the NSF status studies leave many information gaps in this area. Problems connected with testing in biology are apparent. Information regarding student outcomes following instruction in biology in any dimension other than content achievement is scant. Where has such information been collected? How frequently? What is its nature? Information concerning program and student outcomes is needed when one attempts to evaluate a total science program or the biology offerings from a broad perspective.

Examples of testing and general evaluation procedures which emphasize the goals associated with personal needs and societal problems would be useful for

study, for modeling, and for analysis. Information concerning the effect of teacher testing practices upon student learning and attitudes would be useful also. How do frequency and test style affect learning? Do tests designed to assess higher order learnings result in different patterns of performance for different kinds of students? How do the instruments used for evaluation affect student attitudes toward biology? Much of the information in the NSF studies suggest that testing is a problem in biology programs. However, there is a lack of specific information about the effect of various criteria for success on instruction and student outcomes.

Identification of biology programs in which studies of teaching (applied research) have been conducted would be valuable information. When there is an interest in self-assessment, one would expect more change in programs, teaching strategies and student outcomes. As in the case of student outcomes, new curriculum models (courses), and exemplary teacher performance, information regarding model programs of evaluation is needed. Such examples are important for descriptions of discrepancies between desired and actual states. In addition, models provide assistance for others in moving to the desired condition. How can rational decision-making be evaluated? How does a new focus for biology programs (environmental studies, for example) affect student and program evaluation?

In summary, the NSF-supported status studies of 1978 provide much needed information, but a synthesis of the results suggests a series of additional questions. These questions represent gaps in the information base, some of which should have been anticipated prior to these previous studies. As is often the case, however, asking the right questions is easier after the picture begins to form. It is only now, as new hypotheses are generated, that we see the urgent need for filling some of the gaps that appear.

## Needed Research

### Introduction

A comparison of the actual state of biology education, described by the NSF science status studies, with the desired state as proposed by Project Synthesis identified several areas of needed research. First, there were areas in which the three studies indicated the lack of a research base; and, second, new trends were identified which require an extension of the current research foundation. Furthermore, the desired biology program needs to be established on a philosophical and theoretical base. In order, therefore, to effect positive changes in teacher behavior, curriculum development, student outcomes, course content, and societal acceptance of the proposed biology program, new research must be promulgated.

### Priority Research Areas

The biology focus group is cognizant of the priority areas for research identified by the National Science Foundation, and there is extensive matching between the suggested research and the indicated priority areas. First, since biological science is presented during either the middle/junior high school years grades 7 through 9 (ages 12-14) as Life Science or during the 9th and 10th grades (ages 14-15) as beginning biology, the research needed focuses on the early adolescent. Second, the identified research involves basic questions such as the long-range effectiveness of different styles of learning and teaching, strategies for teaching and evaluating effective decision-making or problem-solving processes, applications of methodologies from the social sciences to biology teaching and research, new models of inservice and pre-service teacher education, and effectiveness of biology teachers on research teams. Third, much of the needed research is interdisciplinary because of the desired biology program's involvement in strategies and content from other disciplines such as sociology, anthropology, psychology, and cultural, economic and human geography. The goals (societal needs, personal needs, careers and knowledge of the discipline) of the desired biology curriculum demand a variety of new methodologies for conceptualizing, teaching, and learning biology. Included among the useful methodologies are survey techniques, interviews, ecological studies and case studies. Fourth, much of the needed research may require synthesis studies;

and fifth, since the desired biology program is aimed toward a wider spectrum of people, it should promote scientific literacy. The National Science Foundation's five priority areas of research (early adolescent, interdisciplinary, new methodologies, synthesis and scientific literacy) provide the interactive factors needed to move biology education to the desired state.

#### Nature of Required Research

Much of the research needed requires a new, or broader concept of the nature of educational research. For example, whenever possible, there should be planned replication of studies in a variety of settings and conducted by several research teams. The new methodologies employed, however, may result in investigations which do not fit into the "scientific" mold. It is anticipated that many studies may be multi-causal and nonreplicable; they may be based partly, or wholly on value judgments; they may require a variety of inquiry techniques, including problem-solving and decision-making; and they may not result in a single answer or solution. However, these new types of investigations employing new methodologies and designs may provide both the information and direction needed to transform biology education in our society.

Research is required in the area of learning evaluation also. For example, new instruments must be designed to assess the goals of the new biology, that is, to assess students' abilities to interpret social and personal problems. Studies to explore techniques and attitudes toward seeking and using reliable information are needed as well as ones describing methods of inquiry unique to understanding and solving present biosocial problems.

#### New Research Methodologies

One area of needed research involves the identification or the development of new methodologies of research which are appropriate to the new concept of biology. Research in biological education is in need of new methodologies, which can encompass the complexities, ecologies and interacting variables of the class, the school, and the community. The narrowly defined, controlled, single variable, reductionist bias of contemporary educational research is not adequate for studying the potential of, or for assessing the impact of, the desired biology curriculum. For example, techniques such as role playing, interviews, surveys, meta-analysis and ecological analysis of a classroom need to be applied and examined for use in biology education.

Two areas which require new methodologies are so basic to the changes suggested that they bear special mention. These concern research into problem-solving and decision-making processes, for both are teaching/learning skills in the desired program. Research is needed to describe decision-making processes in children, adolescents and adults; to examine the effects of ideas, values and information on decision-making processes; to examine students' abilities to support assertions for their decisions; to instruct teachers in implementing decision-making skills; to define attributes of decision-makers; and to delineate interactions in the process of decision-making.

Furthermore, research is needed to determine the effectiveness of different models of cooperative as well as individual problem-solving techniques and to determine what facilitates the biology teacher's use of cooperative and individual problem-solving techniques. Since decision-making and problem-solving strategies are crucial techniques for applying biological information in personal and societal contexts, this research is needed to describe appropriate ways to involve students in: (1) reaching decisions, (2) clarifying the consequences of their decisions, and (3) identifying the underlying ethical considerations in reaching decisions.

#### Descriptive Research

Another area of needed research involves the description of biology education, past, present and future. Again, a synthesis of research is needed to describe accurately changes during the past fifty years with respect to facilities, students, courses, inservice models, preservice courses and enrollments. An analysis of courses related to the desired biology program such as HSP and OBIS is needed to determine both the strengths and weaknesses of these and similar offerings. Case studies of new, interdisciplinary courses which describe their effects on students, teachers and communities are suggested. Furthermore, research is needed on the feasibility of basing a biology program on current issues and questions and on using the human organism as the prototype. In addition, research is required to determine the public's perception of biology; that is, factors affecting public understanding of and support for biology; public attitude toward the meaning and importance of biology; and public support of experienced-based biology program.

Since the desired biology program is founded on social and personal awareness of the quality of humanness, research is required to compare different

perceptions of humankind; to clarify the presentation of humankind in biology texts; to describe unique qualities of humanness such as self-awareness, reciprocal obligation, values and ethics; and to illustrate the problems and potentials of humankind interacting with the physical and natural environment. In addition, a continuing program of research and study on social changes, cultural thrusts and science perspectives is needed to establish cultural and scientific validity for the desired biology curriculum. And, last, there is a need for descriptive studies which can establish the educational legitimacy of biology teaching. That is, a conceptual framework or theory consistent with personal and societal needs is required as the foundation for the desired courses.

#### Research on Goals

The new perception of biology includes many interdisciplinary topics considered from personal, societal and career orientations as well as from a knowledge-of-the-discipline base. Research topics needed to illuminate the goals of biology comprise the fourth area of needed research. Studies are needed to determine what knowledge is most related to personal, societal and career goals; to describe the basic concepts and salient knowledge related to social issues and personal needs, and to ascertain what adolescents want to know. Research is appropriate to determine biology teachers' knowledge and values concerning social issues, to develop a hierarchy of important social issues for biology education and to determine what adolescents perceive as important social issues. Furthermore, research concerning personal goals of students and teachers as they relate to biology is needed. Once the goals are clarified and identified research is needed to explain the inconsistencies between the stated goals and the observed goals in biology classrooms and to develop techniques in teacher education which help to eliminate those inconsistencies.

#### Research on Careers

The new biology includes a permeating and pervasive goal of career information, and a variety of research is needed on the feasibility of providing a career orientation within a specific content area. First of all, a synthesis of biology career information is needed. In addition, studies to explore both the impact of different career exploration techniques and the factors influential in the selection of careers are needed.

### Research on the Role of the Teacher

The three NSF status studies describe conclusively the importance of the teacher in determining and in implementing any biology program. Indeed, the teacher has been characterized as being the enabler, the inspiration, and the constraint (CSSE 19:1) of biology education. Considering the central role of the teacher, research is needed concerning teacher behavior and training. In order to interpret and influence the role of the biology teacher, the following research activities are suggested:

1. Follow-up studies to NSF's UPSTEP projects to determine the effect of model programs on teacher behavior.
2. Correlational studies between two teacher-training programs on one campus (for example, Human Biology or General Biology) to determine any differential effects on teacher behavior and/or performance.
3. Analysis of the effectiveness of inservice workshops in areas important in the desired state (social, personal, knowledge of the discipline and careers.)
4. Studies of the effectiveness of different approaches (lecture, video-tape, workshops, active listening, encounter groups) in enabling teachers to personalize instruction.
5. Studies concerning the effects of teachers' content backgrounds on achievement in secondary schools biology and on their teaching styles.
6. Analyses of strategies, including support systems, which affect curriculum changes and teacher actions.
7. Surveys of teachers' perceptions of needed areas of training and research as well as studies concerning ways to influence those perceptions.
8. Studies of communication modes which will encourage more teacher-to-teacher support and growth.
9. Research on the professional socialization of biology teachers and its causes and its effects.
10. Descriptions of biology teachers' use or lack of use of the natural environment and studies of ways to effect its use.
11. Analysis of the resistance to change found in biology teachers, administrators and publishers and studies of ways to effect change.

12. Examination of the current perceptions of biology teachers concerning personal needs, societal issues and career awareness as part of a biology curriculum.

As the above list indicates, comprehensive research is needed to analyze and to alter positively both teacher training and behavior.

#### Research on Classroom Practices

The next area for study is classroom practices. Again, a range of research is needed. For example, studies to explore the new modes of problem-centered instruction, of personalized and individualized instruction and of interdisciplinary curricula are appropriate. Research needs to identify which current problems can be explored reasonably by secondary biology students. A survey of the available materials appropriate for the desired biology program needs to be conducted. Research to determine whether biology teachers prefer designing a curriculum, using one designed for them, or using some combination of the two is crucial. Furthermore, the effectiveness of hierarchical, discipline-based learning in comparison with modular, problem-oriented learning in biology, especially in relation to long-term memory and rational decision-making, needs to be analyzed.

Research on both the feasibility of and the appropriate mechanisms for implementing the desired biology program is required. One special concern of any feasibility study is an analysis of both the activities of and the facilities for the desired biology laboratory. For example, research is needed to:

- (1) assess the problems and possibilities of implementing the desired program;
- (2) determine biology teachers' perceptions of the optimum way to implement it;
- and (3) examine several model implementation programs to assess the effects of setting, grade level and teacher characteristics.

#### Research on Student Outcomes

The final area of research is, perhaps, the most important one -- research on student outcomes. Research concerning student characteristics and learning patterns is needed to assure the appropriateness of any biology program, particularly one heavily based on personal needs and societal issues. One problem which must be examined is how and where students acquire a knowledge of biology. It is recognized that culture, among other things, is a communication system and creates its own conventional wisdom. A science/technology based culture conveys to young people a knowledge about itself that has not been

explored to any degree. How much of what students know is a product of cultural diffusion, and how much has been learned through formal schooling are unknown quantities. How much of students' scientific knowledge is acquired simply from living in a technological society is a critical factor to ascertain before designing new programs. Furthermore, the question "What factors influence the motivational level of students for studying biology?" is of critical importance.

Additional research to determine what biological concepts are appropriate for students in a bio/social context, to explore the relevance/effectiveness of different curricular designs on students, and to develop new criteria for measuring student growth in biological education is needed. Furthermore, as long as discrepancies exist, research which analyzes black, Hispanic and female achievement patterns is needed in order to determine alternative or supplemental instructional strategies in biology for these groups.

Several major areas have been identified as requiring research for the suggested changes in biology education. These areas include all of the research priorities identified by the National Science Foundation, and they will provide a comprehensive background for the projected changes. Biology educators, students, parents and concerned citizens certainly have learned from the last series of curricular reforms that effective changes must be firmly based on research which documents needs, desires and pathways before such changes are accepted, disseminated and utilized. It is hoped that this compilation of needed research will provide the impetus and the justification for the acceptance, dissemination and utilization of the desired biology curriculum.

### Recommended Solutions

In an earlier section the discrepancies between a desired biology program and existing biology programs were reviewed. (See Table I.) Information gaps were then outlined. The discrepancies and information gaps suggested research problems for biology educators. An advantage of using a desired program is that it provides a direction and strategies for the amelioration of biology education problems. The purpose of this section is to outline recommendations that will help resolve the discrepancies. The recommendations are not intended to provide answers. The intention is to suggest strategies, tactics and procedures for the resolution of problems related to biological education.

The approach used in this section will be to first discuss changes in biology education as they relate to public education; second, to describe recommended changes in the professional education of biology teachers; and finally, to discuss the important function of leadership by those directly and indirectly associated with biology education.

#### Public Education

Public education is an in and out-of-school process. That is, public education in biology is more than teaching biology in school. This is a fundamental premise of our recommendations. The biology focus group assumes that there is a need to inform the public about the place and significance of biological information in our society. One place the public is introduced to biology is in school. In addition, there are other educational agencies such as museums and zoos which also have biological programs. Finally, there are other social institutions such as churches and the media which also educate and inform the public. We must assume that some aspects of biology are conveyed to the public via this last, less formal process.

Attaining the goal of a biologically educated public will require that biology educators work cooperatively with each other and with informal agencies (e.g., museums, park systems, 4H Clubs, print and electronic media, church groups) to maximize their contributions to the public's biological experiences. Many of these agencies are in a favorable position to relate biological concepts to the real world of the public. The responsibility of biology educators is to participate and to utilize fully these resources in developing the desired state in her/his own way. Obviously, biology educators at all levels have

different strengths and interests. If each contributes his/her share, the combined effort will indeed have an impact on public education. In the following sections are some suggestions for changes that might be made in curriculum and instruction.

### Curriculum.

In general, the biological curriculum should include much greater emphasis on knowledge and methods related to the personal needs of students, societal problems and career opportunities. Achieving this goal will not be easy but it is possible.

1. Curriculum programs should be constructed so knowledge is presented in the context of personal and social issues.
2. The accumulated knowledge derived from biological research of the last 200 years needs to be re-examined in philosophical and psychological terms to establish the biological concepts having the widest significance in the contexts of current social conditions and prospects for future human endeavors.
3. Worthy educational goals for the teaching of biology must draw upon not only the natural sciences but upon other disciplines dedicated to human understanding, such as anthropology, sociology, psychology, human geography, the arts and humanities.
4. What happens to improve biology teaching will happen only if teachers make it happen. The desired state of biology teaching will come about only as biology teachers individually change their educational perspectives and develop new programs reflecting those perspectives. New perspectives for the curriculum will include some of the following (see The Phase I Biology Report for a complete description or Table I in this report):

- cooperative problem solving
- decision making
- problem orientation (vs. structure of the discipline)
- humankind as central focus of problem
- interdisciplinary analysis of problem
- individualized and personalized instruction

5. Attaining the desired state of biology teaching will require that teachers be heavily involved in developing the new curriculum materials; in contrast, the 1960's curriculum improvement projects involved teachers only in a token way.
6. The development of curriculum programs should be multifaceted. Some textbooks and materials should be developed and implemented as they have in the past. Significant efforts should be directed also toward facilitating the development of biology programs at the local level.
7. Textbooks should be revised so they show an interdisciplinary analysis of social issues that are human-oriented and career-directed.
8. Model laboratories that provide information on problems and then converge on questions and decisions should be developed.

#### Instruction.

Instruction in biology should be human-centered. This recommendation refers to both the curriculum and the interaction between teacher and student. (See Phase I Biology Report or Table I in this report for a complete description.)

1. Biology instruction should be for all students not for just the college-oriented and/or scientifically inclined.
2. Instruction should be interactive among teacher, student and materials.
3. Information processing and decision making should take precedence over accumulating facts and reaching conclusions.
4. Efforts need to be made to establish the function and professional responsibilities of the teacher in modern terms recognizing the evolution and transformation of the biological sciences as they interact with and influence cultural directions. Along these lines the teacher is likely to be more of an interpreter or a parabiologist than is now the case.
5. Instruction could: (1) underscore the uniqueness of human decision-making, (2) emphasize the interaction between information and values in the decision-making process, and (3) stress the unintentional consequences of decisions.

6. Evaluation should focus on the students' ability to: (1) provide evidence justifying decisions concerning problems; (2) consider options and consequences of decisions; and (3) use the best information available.

### Professional Education

Achieving and maintaining the desired biology program will take the combined and coordinated efforts of biology educators at the local, regional and national levels and those in elementary, secondary and higher education.

#### Preservice.

1. Certification programs based on the desired state of biology education specifically for grades 5-9 science teachers (middle/junior high school) should be developed and implemented.
2. Preservice training should include courses stressing inquiry problems, data collection and analysis using techniques from the social sciences, holistic strategies of investigation and more integration with social sciences.
3. Efforts need to be made to bring teacher education in the biological sciences in line with what is expected of biology teachers as they function in a general education capacity. This endeavor has dimensions in both preservice and inservice education.
4. Greater emphasis should be placed on the philosophy and rationale of biology teaching. Students should have a clear and consistent rationale when they enter teaching.
5. Human relations in biology teaching, i.e. listening, responding, etc., should be emphasized as much as planning and organization.

#### Inservice.

1. Biology teachers need to be engaged in continuing efforts to relate the conceptual foundations of biology to educational goals and subsequently to instructional practices. To accomplish this endeavor will require the cooperative efforts of biology educators, sociologists of science, and philosophically inclined biologists.
2. To reverse the dysfunctional aspects of biology teaching as viewed by biologists, parents, educators, and concerned teachers requires a long-term commitment to the reconstruction of the biology curriculum to bring it into harmony with the characteristics of contemporary society.

Presently, educators apparently do not perceive that the biology curriculum is out of phase with contemporary life. This may be the cause of student dissatisfaction with biology and a contributing factor to the public's loss of confidence in school programs.

3. Inservice workshops must involve biology teachers at local levels as well as coordination at the national level. This could be achieved through the existing programs of the National Science Foundation, provided there is more coordination between their programs -- i.e., inservice workshops tied to RISE and/or DISE projects.
4. Inservice programs for biology teachers should be interdisciplinary. That is, there should be attention given to social issues and information from other disciplines such as economics, sociology, and political science. Ethics and values must be incorporated. This perspective will require some input from psychologists and philosophers.
5. Inservice education should stress continual professional growth as opposed to intermittent presentations of new materials, approaches or techniques.
6. Individual biology teachers must become responsible for their own professional development. This recommendation can be facilitated through cooperative interaction with science educators and/or scientists from colleges and universities.
7. In the past, teachers have responded to crisis situations by introducing new programs, gadgets, and slogans which have been unsubstantiated by psychology, philosophy, or research. This approach has proven to be counterproductive. The development of clear rationale, goals and a conceptual framework by individual biology teachers should be an essential orientation of inservice programs.
8. It is not likely that whatever is suggested to attain the desired state of biological education will be implemented nationwide. It is more likely that a higher quality of biological education will arise from a small number of responsive schools, where there is a clear perception of the desired biological goals and where there is a faculty of concerned teachers backed by a supportive administration.

9. Inservice programs should be conducted that orient biology teachers to the use of their natural out-of-school environment.

Professional Organizations.

1. New directions and goals should be developed by organizations with an interest in biology education, e.g., NSTA, NABT, AAAS.
2. Conventions, conferences and journals of professional organizations should reflect the themes and topics of the desired biology programs. Social issues, personal needs and career materials would be included more than they have been recently.
3. Conferences and publications for biology education in leadership roles are needed. Chautauqua-type programs might be implemented.
4. At present, the knowledge-flow system, including the educational researcher, the educational developer, the school organizer and the teacher of biology is in need of strengthening to become more efficient and cost effective. Professional organizations could help provide this vital function.
5. Teachers need to be brought into a network of educational professionals in a way that enables them to profit from what is known about:
  - (1) human growth and development, (2) human learning and retention, (3) societal changes, and (4) advances in the scientific enterprise.
 The various services of professional organizations could fulfill this need.
6. There is a need for a clustering of the reported research on biology teaching in terms of significant topics (concept development, various teaching practices, teacher variables, laboratory learning etc.). A synthesis of the relevant research could be developed also. The "meta-analysis" and normative/theoretical procedures now being tested by researchers provide a means for developing useful results and for generating new hypotheses for further research. Professional organizations should sponsor these activities.
7. The literature of science education should include more discussion of the questions and problems confronting humankind.
8. Professional organizations could present (via journals, convention programs, etc.) alternative futures of humankind and the decision, changes and policies inherent in such futures, e.g., sustainable growth.

9. Conferences, articles and programs clarifying values such as justice, stewardship, prudence and cooperation should be developed.

### Leadership

Clearly there is need for a new direction in biology education. We have suggested a direction through developing a desired biology education program. Obviously, this program has not been developed and implemented. It is equally obvious that the desired program cannot meet the needs of all teachers due to their uniqueness and that of their schools and of their students. All of this speaks to the need for leadership if the potential of the desired program is to be realized.

1. Biology teachers themselves can become leaders in their communities. Setting up public education programs, arranging for speakers, doing workshops or participating in community programs are all possibilities for the biology teacher.
2. Administrators and supervisors can encourage new directions within and outside the school. The desired program as we have described it is in part developed at the local level. There is no existing program to implement. We have provided direction and suggestions based on the best information available. The efforts of school administrators and science supervisors are essential if the ideals described are to become practice.
3. Science educators at the college and university levels are essential also. The next generation of biology teachers should have the new vision as well as the salient knowledge and methods described. Some thought must go into rethinking science education programs, the orientation of basic science courses and the professional educational courses for students.
4. It may also be important for science educators at the college level to take the initiative in starting inservice programs, arranging public speakers for the community, coordinating school/college programs, obtaining grants and doing research as suggested.

This vision of leadership is not that of a single dynamic individual getting the job done. It will take the efforts of many, each doing his/her share. If the job of bringing the desired biology program into existence is to be

achieved. The distance between desired and actual is covered by the work of leaders within biology education. The task is not only worth it, it may be essential for humankind.

In summary, the goals of the desired biology program, i.e., personal needs, social issues and careers, as well as knowledge of the discipline, should be incorporated into biology textbooks, preservice and inservice education, and into the conventions, conferences and publications of professional organizations. Providing a new direction for biology will take the leadership of many individuals at all levels and locations in the educational community. Finally, there is a new orientation that includes educational agencies beyond the school. Biology is fundamental to citizens living in our society. Since the public is educated in a variety of ways through different agencies, it is important to change our perspective from teaching biology in schools to biology education for the public.

CHAPTER 5 /

PHASE I PHYSICAL SCIENCE REPORT: DESIRED

STATE OF PHYSICAL SCIENCE PROGRAMS

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\* This report is based on the work of many people. The initial work was done by a group which included Ron Anderson, Richard Merrill, Lester Paldy, and William Romey. Norris Harms and Stuart Kahl were involved in a major stage of the report's development and substantial contributions were provided by a commissioned paper prepared by Leo Klopfer and Audrey Champagne. Finally, this report reflects the recommendations of the Project's "Synthesis Group" including Paul Hurd, Joseph Piel, Harold Pratt and Wayne Welch.

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Synthesizing the results of several major research studies requires a conceptual framework for organizing the activity. This report is presented with the intent that it will provide this assistance.

This report is not intended to stand alone. Important background for it is provided in the "Synthesis Report" within the context of which this report was prepared and for which some of the work reported here provided a basis. Goal clusters, themes and critical elements are defined below and provide a structure for this report. For a fuller discussion of goal clusters the reader is referred to the "Synthesis Report". The themes for physical science are developed within this paper although a fuller statement on the role of themes throughout Project Synthesis is provided in the main report. Critical elements are divided between the two reports with the ones specific to physical science contained herein.

### Goal Clusters

A synthesis of research finding requires interpretations that are goal dependent. Thus, an early task of Project Synthesis was the consolidation of various science education goals into four goal clusters which could provide an organizing rubric.

1. Personal needs--those goals which pertain to preparing individuals to utilize science in their own lives and to live in an increasingly technological world.
2. Societal issues--those goals which pertain to preparing informed citizens who are able to deal responsibly with science-related societal issues.
3. Fundamental knowledge--those goals which pertain to acquiring and utilizing scientific knowledge.
4. Career preparation--those goals which pertain to acquiring knowledge of the nature and scope of scientific and technological careers and the ability to utilize this knowledge in entering a career.

No particular priority is given to any or all of these goals at this point. They are listed here with the intent of encompassing the majority of goals that various people have for teaching science. As such they provide an organizing rubric that can be used by people having a wide variety of purposes for science education.

Because the results of this project will be utilized by persons with quite varied goals, this organizing rubric is prominent in its reports. Hopefully, the project interpretations will be useful to a variety of persons and not be limited in its utility to those persons having goals similar to those of the project staff.

### Themes

Science is the domain of this study but it must be defined more precisely if it is to provide a basis for interpreting the research under consideration. This definition is given in the form of themes which thread through the various areas of science. These themes are developed within each of five categories of which one, physical science, is the focus of this report (the other four areas are 1) biological science, 2) elementary school science, 3) scientific inquiry and 4) science/technology and society.). The physical science themes presented here characterize and define the field. For example, the nature of matter is a theme which extends throughout the physical sciences. These physical science themes are developed more fully below.

It also should be noted that the themes of these five areas are interrelated. The scientific process themes, for example, pertain to physical science along with all other areas of science. These interrelationships are seen in another way in that elementary school science includes much that is physical science.

### Critical Elements

Yet another dimension is needed for interpreting the research under consideration. This research pertains to education and some means of organizing the educational aspects is essential. For this purpose, the project staff has identified certain "critical elements" which include such matters as student outcomes, teacher characteristics and classroom practices. The full range of these critical elements is developed more fully in the Synthesis Report and selected ones are developed below even more completely as they pertain to physical science.

Goal clusters, themes, and critical elements--these three categories constitute the major conceptual framework for the analysis of research to be undertaken. Further elaboration of the goal clusters is in the Synthesis Report. The sections of this report which follow deal with an exposition of the themes of physical science and an explication of the critical elements as they pertain to physical science. In both of these sections goal clusters provide important points of reference.

### The Domain Of Physical Science

The themes used to describe the physical sciences are both pervasive and inclusive--pervasive in the sense that each theme extends through a major portion of the domain of physical science and inclusive in the sense that they encompass essentially all portions of this domain generally included in lower education.

Before explicating these themes, however, the domain of physical science as used here should be defined in the conventional terms of subject field. As defined here, it includes the earth, atmospheric and space sciences as well as chemistry and physics. Thus, the themes given below are meant to "map out" this total domain.

The themes presented herein are based upon previous work by Audrey B. Champagne and Leo E. Klopfer. They are presented below within the three classes they define.

It should be noted that the set of themes presented here is a "working list" having utility within this project. It is not necessarily accepted by everyone and, of course, there are the lists of similar nature that include many comparable items. The function of the list presented here is to describe the major content of physical science particularly as it pertains to the various levels of the curriculum.

### Physical Primitives

Theme 1--Physical Primitives: A small number of primitive notions lie at the foundation of physical sciences. These physical primitives recur so frequently in the physical science disciplines that the educated person's understanding of them may be considered fundamental. The primitives which are particularly important for students in elementary and secondary schools include: length, area, volume, mass, density, time interval, rate, force and charge.

### Conceptual Schemes

Theme 2--Nature of Matter: All matter in the universe is composed of units which interact. The motion of submicroscopic units of matter accounts for the temperature of matter and changes in the physical state and structure of matter.

Theme 3--Macroscopic Interactions: Interactions among macroscopic units of matter produce changes in position, motion and/or structure.

Theme 4--Conservation of Energy: The total quantity of energy in the universe does not change (as far as we know), and the quantity of energy before any ordinary interaction equals the quantity of energy after the interaction.

Theme 5--Energy Forms and Energy Conversion: Energy exists in various forms. Energy changes from one form to other forms. Cycles and periodicity occur and are appropriately viewed within a systems framework.

Theme 6--Chemical Interactions: Interactions of submicroscopic units of matter with one another and with energy produce changes in chemical bonding and the composition of matter.

Theme 7--Evolution in the Universe: The presently observable features of the earth and the universe are the result of processes and changes that have continued over long periods of time and are still going on now. Change over time is a universal characteristic of the universe.

Theme 8--Epistemology: Physical scientists share certain notions about the nature of scientific knowledge. Such notions of importance for the educated person include: (1) scientific knowledge is tentative and is subject to revision as the results of new inquiries, (2) the content of scientific knowledge about the physical world is a function of the kinds of probes which are used to investigate the physical world, (3) cause and effect relationships are assumed, and (4) models are useful means of developing knowledge.

#### Desired States of the Critical Elements

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 states of education that can be identified as desirable. An important preliminary step of Project Synthesis is to identify many of these desired states. These desired states can then be used as a basis for analyzing the research studies under consideration and interpreting the results of them.

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.

The critical elements to be employed in this process were identified in the Synthesis Report where a rationale is given for their inclusion. In this facet of Project Synthesis, attention is directed to identifying the desired state of each such element given the intent to attain certain clusters of goals.

The following elaboration of the desired state of each of these critical elements is organized by goal cluster, and for some critical elements by theme within each goal cluster. A description of each desired state is presented, often 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, program characteristics, teacher factors, and classroom practices.

#### Student Outcomes

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

#### Goal Cluster I - Personal Needs.

Theme 1: Physical Primitives--recognize the quantifiable aspects of personal matters and apply them effectively (e.g., estimating amount of paint required, effective scheduling, etc.)

Theme 2: Nature of Matter--utilize knowledge of thermostats, evaporative coolers, heat pumps, and common insulating materials.

Theme 3: Macroscopic Interaction--utilize knowledge of the physics of the internal combustion engine and common hydraulic applications, such as power steering and brake systems.

Theme 4: Conservation of Energy--identify the relative energy inputs and outputs of common technological devices.

Theme 5: Energy Forms and Conversion--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.

Theme 6: Chemical Interactions--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.

Theme 7: Evolution in the Universe--recognize the universality of change in one's environment.

Theme 8: Epistemology--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.

Theme 1: Physical Primitives--be able to understand the magnitude of societal problems described using quantifiable data.

Theme 2: Nature of Matter--make some intelligent decisions about energy issues based on a knowledge of the chemistry of fossil fuels, combustion and new materials for solar energy conversion; comprehend the physical principles underlying the problems of energy storage.

Theme 3: Macroscopic Interaction--comprehend the origins and limitations of supply of ground water, fossil fuels, and mineral resources.

Theme 4: Conservation of Energy--comprehend the dangers, potentials and comparative advantages of fusion and fission technologies.

Theme 5: Energy Forms and Conversions--explain the relationship between the polar ice cap size, weather and sea level.

Theme 6: Chemical Interactions--explain how phosphates and nitrates pose pollution problems.

Theme 7: Evolution in the Universe--recognize that human activity can seriously disrupt the natural pattern of change on the earth.

Theme 8: Epistemology--recognize that scientific knowledge is changing and thus 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

Theme 1: Physical Primitives--comprehend, apply, evaluate, analyze and synthesize knowledge of fundamental units; derived units and systems of measurement.

Theme 2: Nature of Matter--comprehend, apply, evaluate, analyze and synthesize knowledge of a) systems, subsystems, and interactions; b) homogeneous and heterogeneous substances; c) chemical elements and compounds; d) conservation of matter; e) heat conductivity, kinetic-molecular theory, gas laws, crystals, and physical states.

Theme 3: Macroscopic Interactions--comprehend, apply, evaluate, analyze, and synthesize knowledge of kinetics, dynamics, astrophysics, mechanics of fluids, geophysics, physical geology, weather and climate.

Theme 4: Conservation of Energy--comprehend, apply, evaluate, analyze, and synthesize knowledge of conservation of energy, laws of thermodynamics, and energy resources.

Theme 5: Energy Forms and Conversions--comprehend, apply, evaluate, analyze and synthesize knowledge of potential and kinetic energy, wave phenomena, sound, light, electro-magnetic spectrum, static and current electricity/electronics, magnetism and electromagnetism, and solar radiation.

Theme 6: Chemical Interactions--comprehend, apply, evaluate, analyze and synthesize knowledge of atomic theory, nuclear physics and chemistry, and geo-chemistry.

Theme 7: Evolution in the Universe--comprehend, apply, evaluate, analyze and synthesize knowledge of historical geology and the evolution of planets, stars, galaxies and the universe.

Theme 8: Epistemology--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:

1. Opportunities should be provided to pursue individual needs, goals and interests, e.g., provision could be made for modularity, a projects approach, or time periods for investigating individual topics:
2. Opportunities are provided to apply science content and processes to real-world problems that have no pat solutions but require trade-offs (optimization).
3. Personal needs, societal issues and career preparation are considered intrinsic to all facets of the science program.
4. Basic concepts of physical science are dealt with in the context of socially relevant problems at some point in the total program.
5. Basic concepts of physical science are dealt with in a discipline-organized pattern at some point in the total program.
6. Opportunities are provided to interact with people working in science including scientists, technicians, and science-related professionals.
7. Illustrations are provided of persons with different life-styles, socio-economic status, ethnicity, and sex participating fully in the scientific enterprise.
8. Emphasis is placed on the means by which scientific knowledge is generated.
9. Within the total program learning experiences are included which provide:
  - a. laboratory experiences including opportunities to acquire information inductively
  - b. out-of-school experiences
  - c. opportunities to look outward from a discipline to find understanding of its problems
  - d. illustrations of different problem-solving styles
  - e. exploratory activities that involve risk-taking, guessing, hypothesizing, etc.
  - f. opportunities to participate in actual or simulated research activities
  - g. opportunities to develop more advanced mathematical techniques as applied to science matters
  - h. opportunities to develop report and writing techniques
  - i. opportunities to develop ability to read science materials

#### Teacher Factors

Many of the desired characteristics are not unique to physical science teachers. Among these characteristics are: open-mindedness, acceptance of individuals,

creativity, fluency of ideas, patience, warmth, supportiveness, enthusiasm, ability to work intuitively and spontaneously, positive attitudes toward schools and students and interest in science. Science teachers should have an appropriate collection of teaching skills such as the ability to diagnose student learning requirements and chose instructional approaches consistent with the various science teaching goals. In addition to such desired general characteristics, physical science teachers should:

1. be able to comprehend, apply, analyze, evaluate and synthesize the fundamental knowledge of the physical sciences as described by the themes given above,
2. be able to analyze and evaluate alternative solutions for societal issues, based on related knowledge,
3. understand the application of physical science knowledge to a wide range of personal needs, and
4. have an extensive knowledge of science-related careers.

#### Classroom Practices

Classroom practices should utilize the appropriate materials and equipment for the physical sciences. In general, however, the practices involved are not unique to the physical sciences alone but apply to all science teaching. A significant fraction of the instruction should utilize laboratory experience and student involvement with science materials. Safety practices appropriate to the physical sciences should be utilized.

Goals, themes and critical elements, all are an important part of the conceptual framework to be used in synthesizing the results of the several major science education studies under consideration. The above conceptual framework is proposed for use in the physical science portion of this task.

CHAPTER 6

PHASE II PHYSICAL SCIENCE REPORT : THE  
ACTUAL STATE OF PHYSICAL SCIENCE EDUCATION

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### Introduction

Given the current climate of uncertainty about whether or not U.S. elementary and secondary schools are achieving their goals in the area of science education, it is timely to address the question of "What is the actual state of science education?" The four NSF-funded studies which are the focus of Project Synthesis provide considerable insight into this question. In this Phase II Report these four studies will be the source of extensive information and documentation for a description of this actual state of physical science education. As such, this description constitutes the basis for the recommendations which will be presented in Phase III.

In Phase I the Physical Science Focus Group developed a conceptual framework which included goal clusters, themes and critical elements. The critical elements will form the organizing framework for this Phase II Report in that a more extensive amount of information in the four studies speaks directly to matters identified in the critical elements and the critical elements do provide the best perspective from which to provide a description of the actual state of science education. Within this framework specific reference is made to various goal clusters and to physical science as appropriate within each critical element.

### Objectives

The science curriculum of U.S. schools has remained relatively stable during the last two decades (OSU 170) and varies little from one place to another as evidenced by data given in both the RTI and CSSE 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" (CSSE 12:1). This picture is further substantiated by the fact that high school graduation requirements in science typically are only one year (RTI 24-26) and that the average time spent on science K-6 is much less than on mathematics, and somewhat less than on social studies (RTI 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 (RTI 158). This relative position of science education with respect to the rest of the curriculum is rather consistently held by teachers, administrators and parents (CSSE 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 (OSU 175); yet, this value and the increasing emphasis upon technological and societal issues (OSU 182-183) is not reflected in school practice or the views of teachers and administrators.

The difference in objectives found between the practitioners in the schools and the specialists in curriculum 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 a part of general education. Even though one of the aims of science education as seen by practitioners is to provide some exposure to science for all students, it is a utilitarian goal fostering achievement at a very minimal level of competence. In general classes, there is a tendency to teach things that students can relate to and avoid abstractions (CSSE 12:41-42).

By and large science is not seen as particularly important except for the more highly motivated or gifted students (CSSE 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 (RTI). 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" (CSSE 19:8).

Another view of the objectives of science education as practiced in the schools is acquired by looking at the role of "inquiry". A very significant finding was that "very little inquiry teaching was occurring" (CSSE 12:4). Those few teachers who value inquiry teaching also find it difficult (CSSE 12:7). By and large, students and parents both are satisfied with the situation and not concerned that education be focused upon creative challenges or critical thinking (CSSE 12:5). Empirical investigations are given little emphasis; the focus is getting the right answer. There is an emphasis on authority rather than on inquiry. This situation is yet another indication of the tension between the

expectations of scientists and science educators on the one hand and parents and practitioners on the other (CSSE 12:9-10).

This difference in outlook is apparent again in examining the "back-to-the basics" movement as viewed by various people. Even though most school practitioners give some importance to science and see the trend away from science is having potential long-term negative effects, basic skills have pre-empted science. "The problem is that superintendents, as well as the rest of the school people, have partially accepted the position that students cannot learn science until they have shown proficiencies in reading and math" (CSSE 17:20).

In trying to understand the situation and determine why science is given the relative importance that it is, one must examine school scene closely enough to see what the real primary objectives are. According to the CSSE study, socialization is the 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. (CSSE 19:5)"

Another critical factor is the pervasive emphasis upon preparation for later work. The implicit objectives of science objectives which emerge from the CSSE study 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 large. While attention often is given to "things that will be useful in everyday living" (CSSE 12:45), one also gains the impression that this focus is the result of other concerns, such as socialization, rather than the result of high priority being given to personal needs per se. It is important to note that health and nutrition education is often viewed by students and teachers

as being unrelated to school science. In the elementary schools, for example, teachers assigned "health" studies a higher priority than they do "science" suggesting that the two subjects are not treated in an integrated manner. At the secondary level, health may be taught by physical education teachers or health specialists; the science teacher is often involved only peripherally.

The interface between science, technology and society 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 (CSSE 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. It is also interesting to note that these topics are not avoided because of their controversial nature. Teachers seem not to be afraid of such issues and are able to handle them without getting into difficulty. They avoid this controversy by not taking a personal or advocacy position (CSSE 12:28-29). To some extent, the failure of school science to deal with societal issues must surely stem from the schools' insularity; schools which make little attempt to involve members of the community in curriculum and learning or the development of educational goals are likely to assign a high priority to the inclusion of societal issues in the science syllabus.

Although fundamental scientific knowledge takes second place to the basics such as reading, arithmetic and spelling, as noted previously, it is clear that fundamental knowledge takes precedence over the other three goal clusters. The focus of 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. The curriculum is "text-bound" but many texts show the influence of the NSF-supported curriculum reform movement of the 1960's. Teachers have a wealth of good materials to choose from in teaching the fundamental knowledge of the science discipline.

As with personal needs and societal issues, career preparation is not given high priority in the science curriculum. While vocational reasons for taking science are often cited, it also appears that this rationale has not substantially affected the curriculum. Science is assumed to be important for career preparation but career preparation is not built into the program. References to career options or sources of career information are rarely found in textbooks or course syllabi.

"Science education aims to prepare youngsters for work - or at least for vocational training. For this aim, science is often closely identified with technology. The preparation ethic . . . is pertinent to what is said . . . . There was a strong sense that what mattered most was what could be used in one's next studies, and that those, or the one after those, were related to what one would be doing on the job (CSSE 12:22).

#### Student Outcomes

The major source of information on student outcomes is that contained in the reports of the National Assessment for Educational Progress. This information is of particular interest as it relates to relative outcomes within 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 IV is reflected in the student outcomes as measured by the NAEP Science Assessment. For instance: (a) only about 20% 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 think that the major cause of air pollution in large cities is factories.

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, however, it is last in popularity behind the other three basic academic areas: mathematics, english and social studies.

Test results indicate that girls do not achieve as well in science as boys do and the CSSE study goes on to note that "social influences, primarily sex-role socialization, seem to be the basic factors underlying sex differences in science and mathematics achievement and course taking" (CSSE 15:33). It should also be noted that the performance of ethnic minority students is not as high as others.

With respect to measurement of student outcomes, another fact is of interest. In states with minimal competency testing, science is often not included (OSU 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 characterized by remarkable similarities across the various school systems studied. While there commonly is a great diversity of science offerings within a given school setting, in terms of both the courses offered and the

teaching styles employed, this diverse picture apparently is found 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 school level. The data clearly shows that middle school students take courses in physical science, but at the senior high school level most students do not take physical science (RTI 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 CSSE study 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" (CSSE 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 (CSSE 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 CSSE personnel only three were identified where 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'" (CSSE 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 text-books" (RTI 79-85, 97). Many teachers feel a need for assistance in implementing inquiry/discovery approaches (RTI 148).

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 short run, covered quite different ground; that they felt strongly about this opportunity and privileged 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" (CSSE 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" (CSSE 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 (CSSE 12:42). Environmental concepts, societal concerns, interdisciplinary relationships and world problems are emphasized in a variety of courses that have been developed (OSU 30). Both the number of alternative materials available and enrollments in such courses have been on the increase (OSU 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 (CSSE 12:44).

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 . . ." (CSSE 13:63). Laboratory exercises where used tend to be just that - exercises - rather than explorations of genuine phenomena in settings where 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 (OSU 30). It was noted in the CSSE study 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 (RTI 103).

With respect to individualized and self-paced instruction it appears that a very small number of students receive this mode of instruction in spite of the efforts that have been made to promote their use in recent years (OSU 35). Audio-tutorial or videotape courses were not mentioned by any observers in the CSSE 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 (CSSE 13:7). Approximately half of the science teachers view it as at least "somewhat of a problem" (RTI 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. So sample analyses were conducted of some textbook materials in view of their overriding importance. While it was reported in the OSU study that the materials produced in the last two decades place less emphasis on "practical" science, and until recently, at least, give little attention to the interaction of science and society, a more thorough examination clearly was in order.

The net result of the sample analyses 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 great as compared to that given to fundamental knowledge. In physics, for example, the materials range from textbooks which make only a passing reference to societal issues to 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 16mm 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 textbooks used in schools give no significant attention to these matters.

### Program Dissemination

Information about new materials and programs are disseminated through a wide variety of means. The popular sources include professional meetings, journals, publishers' representatives, teachers, principals, courses and NSF institutes. Other teachers and college courses are most frequently mentioned with local in-service programs being cited frequently by elementary teachers but not by secondary teachers. About half of grades 10-12 teachers, one-third of grades 7-9 science teachers and 80% of state science supervisors indicated they had participated in an NSF institute. Teachers who had participated in NSF institutes recalled them with much pleasure and considered them to be of considerable value (RTI 71-76).

In spite of the wide variety of means of dissemination, teachers' perceptions are that their needs are not completely met in this regard. At all grade levels the list of their needs is headed by "learning new teaching methods" and "obtaining information about instructional materials" (RTI B-106-115). Forty-three percent of teachers indicated they do not receive adequate assistance in obtaining information about instructional materials (RTI 148).

### 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 (RTI 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 (CSSE 17:9). This decision-making process in terms of curriculum obviously is worthy of further study.

The CSSE report generally concluded that teacher support systems are weak and in need of vitalization. Although many agencies exist to provide support to science teachers, claims are often made that teachers go without sufficient aid. While some teachers suggest that support personnel are not aware of the classroom situation, they clearly express the need and desire for assistance in the form of teacher institutes, centers, and other forms of in-service (CSSE 19:12-15). 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" (CSSE 16:43).

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

It is also apparent that there are some obvious conflicts between the norms or expectations of teachers and other people who work outside the classroom setting. For example, it was noted that "teachers and supervisors emphasize different purposes and values" (CSSE 16:43). A similar conflict is noted between teachers and college/university personnel. "It was clear to us that the school had a set of social norms (ways students were supposed to behave) which conflicted with the norms teachers were taught to espouse in teacher training courses. Not only the education courses has dysfunctional norms; the liberal arts norms were substantially the same" (CSSE 16:5). Even though the above conflicts had been noted, and it was clear that the inquiry approach commonly espoused in teacher institutes is widely accepted, it was also pointed out "that the (NSF teacher) institutes have been seen to have a good impact . . . . Among many federal programs in support of curriculum and teaching, the institutes were mentioned to us most often and in a positive vein" (CSSE 16:53).

A final matter of note is that teachers seem to view universities as having a potentially useful role in developing curricular materials. When asked what universities could do to most help teachers, junior high school science teachers chose the option "develop curriculum more appropriate to the times" much more often than any of other options which included conducting inservice workshops, offering

courses for teachers, establishing teacher centers and sponsoring mutually supportive teacher networks.

### Program Implementation

#### Exposure

The actual implementation of science programs in the schools is best described in terms of course offerings, enrollments and materials utilized. Of the many textbooks available for use in science classes, a relatively small proportion constitutes the majority of books actually in use. Thus, the programs implemented are characterized by a few of the well-known textbooks. In terms of the curriculum reforms of science education of the last couple of decades, the degree to which they have met their goals in terms of implementation in the schools is still a subject of debate (OSU 105). In view of the previous information presented about the manner in which courses were taught and the degree of uniformity among textbooks in terms of the relative emphasis upon the four goal clusters, however, a fairly good picture of science program implementation is obtained by looking at the enrollments in various courses.

While the data indicates that the percentage of students taking science courses at both the grades 7 - 9 and 10 - 12 levels has increased since 1955, in the last few years it has remained relatively constant, or in a few instances shown a slight reduction. Earth science courses have experienced a rapid expansion from 1955 through the 1970's (OSU 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 last 1950's is a substantial increase in the number of alternative science courses being offered to students (OSU 29).

With respect to physical science, several enrollment trends are of interest. Enrollments in general science-type 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 (OSU 71). For a large percentage of students the last physical science course they get is in the 9th grade. About 50% of secondary school students complete their last science course in the 10th grade, but in the vast majority of cases this is biology (OSU 36-37).

## Teachers

The Case Studies (CSSE) 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 the 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 view of the key role played by the teacher as described above, any insights gained as to teachers' philosophy and mode of operation will be most valuable in understanding how schools operate and 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 (CSSE 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 (CSSE 16:7):

"We saw the science teacher working conceptually as influenced by three poles: (1) the ethic of scientific inquiry; (2) the 'ideal' science teacher role; (3) socialization responsibilities" (CSSE 16:7). As a result of these three poles, and the fact that these teachers did not give them the same relative importance as science education specialists and curriculum specialists, we have the conflict cited earlier (CSSE 16:8).

Thorough examination of the CSSE 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 outlook that teachers and the best school personnel have about educational objectives and practices (CSSE 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 (CSSE 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 (CSSE 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 (CSSE 16:22). "Putting it in a nutshell, most teachers seem to treat subject matter knowledge as evidence, and subject matters 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" (CSSE 16:24).

Given this view of who teachers are and the outlook on the system within which they work, it is relevant to consider the modes of professional development available to them and the extent to which they are utilized. It was found that the "teacher is engaged in occasional staff meetings, a diminished program of inservice training, and some continue to enroll in university courses . . ." But, ". . . continuing professional education activities were meager" (CSSE 16:48). It is also relevant to note that by and large teachers worked alone. In addition, teachers indicated that they read an average of seven articles and four books of a professional nature each year. The authors of the CSSE study claim that the impact of this reading on their teaching is not extensive (CSSE 12:7).

Teachers are not convinced the "system" is very supportive of them. They do not praise college-level courses, they feel frustrated with student motivation, and feel unsupported in terms of pay, budget and recognition.

In addition to this information on teachers' attitudes and general outlook on education, students and the system of which they are part, it is important to note some of the more tangible information about their preparation for the job they are performing. Their preparation and the organizational structure within which they utilize this preparation is relevant.

From grades 4 to 8 the percentage of instruction offered by special science teachers increases with grade level. At the secondary level science is taught mostly in departmentalized subject areas. While some team-teaching situations exist, the great majority of science teaching is offered by teachers in single teaching situations (OSU 14).

In terms of their preparation, it should be noted that elementary school teachers rarely are required to take more science content in their undergraduate programs than that required of them in the general education component. Certification for secondary school science teaching, on the other hand, usually requires a minimum of 24-36 semester hours of science (OSU 50). When junior high school science teachers are considered as a separate sub-group of secondary school science teachers, these people (on the whole) lack depth in more than one area of science. Yet, many fill general science teaching assignments (OSU 71). General science teachers had depth in biology or physical science. Relatively few had depth in more than one area. Earth science teachers had the least preparation in their major teaching area. The majority of both chemistry and physics teachers had reasonable preparation in their particular field.

Given the above picture of science teachers, it is apparent that their attitudes toward education, and in particular the educational goals which in practice they tend to value, is of major importance. Given this picture of the substantial influence of teachers, their view of the educational process and educational institutions, and the mechanisms currently in place to cause changes in teachers, it is apparent that any attempts to bring about change in science education must give major attention to this extant situation.

### 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 CSSE study 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 (CSSE 15:6-7). "With or without regrets 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 media because of the efficiency involved" (CSSE 15:7).

While adequacy of science facilities is perceived as one of the most important conditions necessary to a good science program (OSU 38) and approximately 25% of

teachers reporting in the RTI survey indicated that facilities presented serious problems, one receives 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 questionnaires 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 used to reinforce formal classroom work. This trend is likely to be accelerated by the movement toward "basic" education which will surely increase the pressures 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 the 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.

Little imaginative use is made of media in American science classrooms if the Case Studies schools are typical. Aside from the showing of an occasional 16mm film, use of the overhead projector and perhaps a filmstrip, the classes described do not appear to be particularly modern. Few of the Case Studies reported the use of any techniques which involve contemporary technological advances.

Another matter that can be noted with respect to classroom practices is the extensive use of testing in the schools, which is accepted as a very natural part of the school setting (CSSE 15:12). On the other hand, it is claimed that teachers make very little use of the information they acquire by testing (CSSE 15:21). The obvious question then is why teachers are making increasingly greater use of tests. "Although formal testing did not seem to satisfy most of the teachers' need to know what the students knew, testing did seem to assist in socializing students and maintaining control over them" (CSSE 15:23).

In summary, the picture one acquires from these studies suggests that instructional practices 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 that 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 (CSSE 15:23). Sixty to seventy percent of grades 7 - 12 teachers felt that "lack of student interest in subject" was at least somewhat of a problem (RTI 158).

Another student characteristic that poses a learning difficulty as perceived by teachers is poor reading ability. Seventy to eighty percent of teachers, grades 4-12, feel that "inadequate student reading abilities" is a moderate to serious problem (RTI 158). It is reported that 40-44% of secondary principals agree with teachers about reading problems, but few perceive lack of student interest as a problem in science (RTI B131).

The matter of student motivation can be viewed with respect to the grading system. Competition in the classroom and the grading system are an important positive contribution to motivating the academically able student (CSSE 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 are somewhat interested in grades, is substantiated by data other than that reported in these studies (CSSE 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 (C03A01) and they definitely are willing to get actively involved in helping to solve world problems (C03A02). More students than not indicate that they use scientific approaches when solving problems outside of science class (C04A07) and most feel that science and technology can help solve such problems as pollution, disease, and drug abuse (C05A02).

On the other hand, only about half of the students seem to know that science 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 insight 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 careers that will use science (OSU 35). The average student gets no physical science in senior high school.

### Evaluation

Attention to accountability is on the increase and the assumption that it is of value for schools is not being challenged (CSSE 17:10). This movement toward accountability is reflected in minimum competency tests, criteria-referenced diagnostic tests, and standardized achievement tests. "We found no actual evidence of the validity of these accountability procedures. But, neither teachers nor technical people at the district were seen to be raising questions about validity" (CSSE 17:11). It also is interesting to note that even though these approaches to accountability emphasize objective measures of student performance, most expressions of the performance of the schools were in terms which reflected the reasons why the schools were supported by the community (CSSE 17:11).

The testing employed in schools includes both teacher-made tests which are used quite frequently and standardized tests administered by the district. Science standardized tests were used in 43% of the K-6 schools and 33% of the 7-12 schools. (RTI 27-37). The most frequently reported use of the results of the standardized science tests was for reporting results to teachers and parents. The moderate use cited for revising curricula and planning inservice education was noted mainly at the K-6 level (RTI 200-202).

Even though evaluation as described here was valued, there were reservations about the cost of it in terms of instructional time. "Many teachers spoke highly of the increased manageability of instruction through objectivication but objected to instructional time diminished by time taken by testing and were apprehensive about what might be done outside the classroom with test scores" (CSSE 22:14).

### Summary

The overall impression that one receives from the four studies is mixed. Clearly, many worthwhile things are taking place in school science even as support for science in the curriculum declines. On the other hand, an examination of contemporary school science in terms of the four broad goal clusters suggests that much of what is taking place is mismatched to the needs and interests of the majority of American youth. A problem as multi-faceted as this one will require a variety of approaches before it is likely to be completely appreciated, much less solved.

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CHAPTER 7

PHASE III PHYSICAL SCIENCE REPORT :  
THE STATUS AND NEEDS OF  
PRECOLLEGE PHYSICAL SCIENCE EDUCATION

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## Preface

The physical science focus group of Project Synthesis was tasked with synthesizing the results of several major research studies. The purpose of this endeavor was to gain an understanding of the actual status of physical science education which would then lead to recommendations for improving science programs.

During the initial stage of the study, a conceptual framework was developed to organize the subsequent synthesis activities. The section entitled "The Desired State of Physical Science Education" describes this "perspective" from which the group operated. Subsequent sections present the group's conclusions regarding the status of existing programs and recommendations for improving them.

The domain the group was asked to investigate went beyond just the physical sciences to include earth science as well. While the number of course offerings in earth sciences has increased in recent years, the physical sciences of chemistry and physics far overshadow earth science in terms of emphasis at the secondary level. (The last exposure of most students to either physical or earth science is at the junior high school level.) This report relies on a broad definition of the physical sciences but does refer to earth science when presenting information specific to that area.

### Introduction

This section, which describes the conceptual framework used by the physical science group in synthesizing the literature, is not intended to stand alone. Important background for it is provided in the general "synthesis report". The physical science perspective is consistent with the general organizational structure for all of Project Synthesis. The aspects of that structure most pertinent to the work of the physical science group are described below:

### Goal Clusters

A synthesis of research findings requires interpretations that are goal dependent. Thus, an early task of Project Synthesis was the consolidation of various science education goals into the four goal clusters below which could provide an organizing rubric:

1. Personal Needs. Those goals which pertain to preparing individuals to utilize science in their own lives and to live in an increasingly technological world.
2. Societal Issues. Those goals which pertain to preparing informed citizens who are able to deal responsibly with science-related societal issues.
3. Fundamental Knowledge. Those goals which pertain to acquiring academic knowledge of science.
4. Career Preparation. Those goals which pertain to acquiring knowledge of the nature and scope of scientific and technological careers and the propensity to utilize this knowledge in making career decisions.

No particular priority is given to any or all of these goals at this point. They are listed here with the intent of encompassing the majority of goals that various people have for teaching science. As such, they provide an organizing rubric that can be used by people having quite varied purposes for science education.

### Themes

Science education is the focus of this study, but the domain of science itself must be defined more precisely if it is to provide a basis for interpreting the research under consideration. The needed definition is given in the form of themes which thread through the various areas of science. These themes are developed

within each of five categories of which one, physical science, is the focus of this report (the other four areas are biological science, elementary school science, scientific inquiry and science/technology and society). The physical science themes presented here characterize and define the field. For example, the nature of matter is a theme which extends throughout the physical sciences. These physical science themes are developed more fully below.

It should be noted also that the themes of the five focus areas are inter-related. The scientific process themes, for example, pertain to physical science along with all other areas of science. These interrelationships are seen in another way in that elementary school science includes much that is physical science.

### Critical Elements

Yet another dimension is needed for interpreting the research under consideration. This research pertains to education and some means of describing and organizing educational matters is essential. For this purpose, the project staff has identified certain "critical elements" of education such as student outcomes, teacher characteristics and classroom practices. These critical elements are developed more fully in the general synthesis report, and selected ones are developed below even more completely as they pertain to physical science.

Goal clusters, themes and critical elements -- these three categories constitute the major conceptual framework for the analysis of research to be undertaken. The major sections of this report which follow deal with an exposition of the themes of physical science and an explication of the critical elements as they pertain to physical science. In both of these sections goal clusters provide important points of reference.

### The Domain of Physical Science

The themes used to describe the physical sciences are both pervasive and inclusive; pervasive in the sense that each theme extends through a major portion of the domain of physical science and inclusive in that each encompasses essentially all portions of this domain generally included in elementary and secondary education. Before explicating these themes, however, it should be noted that the domain of physical science as used here includes the earth, atmospheric and space sciences as well as chemistry and physics. Thus, the themes given below are meant to "map out" this total domain.

The theme structure presented here is the result of previous work by Audrey B. Champagne and Leo E. Klopfer. They are presented below within the three classes they defined.

It should be noted that the set of themes presented here is a working list,

having utility within this project. It is not necessarily accepted by everyone and, of course, there are other lists of a similar nature that include many comparable items. The function of the list presented here is to describe the major content of physical science particularly as it pertains to the various levels of the curriculum.

### Physical Primitives

Theme 1: Physical Primitives. A small number of primitive notions lie at the foundation of physical sciences. These physical primitives recur so frequently in the physical science disciplines that the educated person's understanding of them may be considered fundamental. The primitives which are particularly important for students in elementary and secondary schools include: length, area, volume, mass, density, time interval, rate and force.

### Conceptual Schemes

Theme 2: Nature of Matter. All matter in the universe is composed of units which interact. For example, the motion of submicroscopic units of matter accounts for the temperature of matter and changes in the physical state and structure of matter.

Theme 3: Macroscopic Interactions. Interactions among macroscopic units of matter produce changes in position, motion and/or structure.

Theme 4: Conservation of Energy. The total quantity of energy in the universe does not change (as far as we know); and the quantity of energy before any ordinary interaction equals the quantity of energy after the interaction.

Theme 5: Energy Forms and Energy Conversion. Energy exists in various forms. Energy changes from one form to other forms. Cycles and periodicity occur and are appropriately viewed within a systems framework.

Theme 6: Chemical Interactions. Interactions of submicroscopic units of matter with one another and with energy produce changes in chemical bonding and in the composition of matter.

Theme 7: Evolution in the Universe. The presently observable features of the earth and the universe are the result of processes and changes that have continued over long periods of time and are still going on now. Change-over time is a universal characteristic of the universe.

### Epistemology

Theme 8: Epistemology. Physical scientists share certain notions about the nature of scientific knowledge. Such notions of importance for the educated person include: (1) scientific knowledge is tentative and is subject to revision as the result of new inquiries; (2) the content of scientific knowledge about the physical world is a function of the kinds of probes which are used to investigate the physical world; (3) cause and effect relationships are assumed; and (4) models are a useful means of developing knowledge.

### The Desired States of the Critical Elements

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.

The critical elements to be employed in this process were identified in the Synthesis report where a rationale is given for their inclusion. In this report attention is directed to identifying the desired state of critical elements given the intent to attain certain clusters of goals. A description of each desired state is presented often 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, program characteristics, teacher factors and classroom practices.

#### 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.

- Theme 1: Physical Primitives. Recognize the quantifiable aspects of personal matters and apply them effectively (e.g., estimating amount of paint required, effective scheduling, etc).
- Theme 2: Nature of Matter. Utilize knowledge of thermostats, evaporative coolers, heat pumps, and common insulating materials.
- Theme 3: Macroscopic Interactions. Utilize knowledge of the physics of the internal combustion engine and common hydraulic applications, such as power steering and brake systems.

- Theme 4: Conservation of Energy. Identify the relative energy inputs and outputs of common technological devices.
- Theme 5: Energy Forms and Conversion. 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 ultra-violet radiation.
- Theme 6: Chemical Interactions. 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.
- Theme 7: Evolution in the Universe. Recognize the universality of change in one's environment.
- Theme 8: Epistemology. 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

- Theme 1: Physical Primitives. Be able to understand the magnitude of societal problems described using quantifiable data.
- Theme 2: Nature of Matter. 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.
- Theme 3: Macroscopic Interactions. Comprehend the origins and limitations of supply of ground water, fossil fuels, and mineral resources.
- Theme 4: Conservation of Energy. Comprehend the dangers, potentials and comparative advantages of fusion and fission technologies.
- Theme 5: Energy Forms and Conversions. Explain the relationship between the polar ice cap size, weather and sea level.
- Theme 6: Chemical Interactions. Explain how phosphates and nitrates pose pollution problems.
- Theme 7: Evolution in the Universe. Recognize that human activity can seriously disrupt the natural pattern of change on the earth.
- Theme 8: Epistemology. Recognize that scientific knowledge is changing and thus 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.

- Theme 1: Physical Primitives. Comprehend, apply, evaluate, analyze and synthesize knowledge of fundamental units, derived units and systems of measurement.
- Theme 2: Nature of Matter. 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.
- Theme 3: Macroscopic Interactions. Comprehend, apply, evaluate, analyze and synthesize knowledge of kinetics, dynamics, astrophysics, mechanics of fluids, geophysics, physical geology, weather and climate.
- Theme 4: Conservation of Energy. Comprehend, apply, evaluate, analyze and synthesize knowledge of conservation of energy, laws of thermodynamics and energy resources.
- Theme 5: Energy Forms and Conversions. 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.
- Theme 6: Chemical Interactions. Comprehend, apply, evaluate, analyze and synthesize knowledge of atomic theory, nuclear physics and chemistry, and geo-chemistry.
- Theme 7: Evolution in the Universe. Comprehend, apply, evaluate, analyze and synthesize knowledge of historical geology and the evolution of planets, stars and galaxies and the universe.
- Theme 8: Epistemology. 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:

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

### Teacher Factors

Many of the desired characteristics are not unique to physical science teachers. Among these characteristics are: open-mindedness, acceptance of individuals, creativity, fluency of ideas, patience, warmth, supportiveness, enthusiasm, ability to work intuitively and spontaneously, positive attitudes toward schools and students, and interest in science. Science teachers should have an appropriate collection of teaching skills such as the ability to diagnose student learning requirements and choose instructional approaches consistent with the various science teaching goals. In addition to such desired general characteristics, physical science teachers should:

- be able to analyze and evaluate alternative solutions to societal issues, based on related science knowledge;
- understand the application of physical science knowledge to a wide range of personal needs;
- be able to comprehend, apply, analyze, evaluate and synthesize the fundamental knowledge of the physical sciences as described by the themes given above; and
- have an extensive knowledge of science-related careers and the utilization of scientific knowledge within them.

### Classroom Practices

In general, desired practices are not unique to the physical sciences alone but apply to all science teaching. Classroom practices should utilize the appropriate materials and equipment for the physical sciences. A significant fraction of the instruction should utilize laboratory experience and student involvement with the science materials. Safety practices appropriate to the physical sciences should be utilized.

Goals, themes and critical elements are an important part of the conceptual framework to be used in synthesizing the results of the several major science education studies under consideration. The above conceptual framework was developed for use in the physical science group's portion of this task, the results of which are reported in the following sections of this report.

### Introduction

Given the current climate of uncertainty about whether or not U.S. elementary and secondary schools are achieving their goals in the area of science education, it is timely to address the question of "What is the actual state of science education?" The four studies which are the focus of Project Synthesis provide considerable insight into this question (Helgeson and Blosser, 1977; Stake and Easley, 1978; Weiss, 1978; NAEP, 1978). These four studies were the source of extensive information and documentation for the description of the actual state of physical science education which follows. This description constitutes the basis for the recommendations which will be presented in the final section of this report.

In the previous section the physical science focus group developed a conceptual framework which included goal clusters, themes and critical elements. The critical elements will form the organizing framework for this section since the extensive amount of information in the four studies speaks directly to matters identified in the critical elements, and the critical elements do provide the best perspective from which to provide a description of the actual state of science education. Within this framework specific reference is made to various goal clusters and to aspects of critical elements specific to physical science.

### Objectives

The science curriculum of U.S. schools has remained relatively stable during the last two decades (OSU 170) and varies little from one place to another as evidenced by data given in both the RTI and CSSE 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 (CSSE 12:1). This picture is further substantiated by the fact that high school graduation requirements in science typically are only one year (RTI 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 (RTI 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 (RTI 158). This relative position of science education with respect to the rest of the curriculum is rather consistently held by teachers, administrators and parents (CSSE 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 (OSU 175); yet, these concerns and the desire for increasing emphasis upon technological and societal issues (OSU 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 some exposure to science for all students. It is in regard to a utilitarian goal that a very minimal level of competence is accepted. In general classes there is a tendency to teach things that students can relate to and avoid abstractions (CSSE 12:41-42).

By and large science is not seen as particularly important except for the more highly motivated or gifted students (CSSE 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 (RTI). 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" (CSSE 19:8).

Another view of the objectives of science education as practiced in the schools is acquired by looking at the role of "inquiry". A very significant finding was that "very little inquiry teaching was occurring" (CSSE 12:4). Those few teachers who value inquiry teaching also find it difficult (CSSE 12:7). Generally students and parents both are satisfied with the situation and not concerned that education be focused upon creative challenges or critical thinking (CSSE 12:5). Empirical investigations are given little emphasis; the focus is getting the right answer.

There is an emphasis on authority rather than on inquiry. This situation is yet another indication of the tension between the expectations of scientists and science education specialists on the one hand and parents, teachers and administrators on the other (CSSE 12:9-10).

This difference in outlook is apparent again in examining the "back-to-the-basics" movement as viewed by various people. Even though most school practitioners give some importance to science and see the trend away from science as having potentially long-term negative effects, basic skills have pre-empted science. "The problem is that superintendents, as well as the rest of the school people, have partially accepted the position that students cannot learn science until they have shown proficiencies in reading and math" (CSSE 17:20).

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 CSSE study, 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" (CSSE 16:25).

Another critical factor is the pervasive emphasis upon preparation for later work. The implicit objectives of science instruction which emerge from the CSSE study 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. While attention often is given to "things that will be useful in everyday living" (CSSE 12:45), one also gains the impression that this

focus is manifested in efforts to "socialize" students rather than to present science information for students' personal needs per se. It is important to note that health and nutrition education is often viewed by students and teachers as being unrelated to school science. In the elementary schools, for example, teachers assigned "health" studies a higher priority than they do "science" suggesting that the two subjects are not treated in an integrated manner. At the secondary level, health may be taught by physical education teachers or health specialists; the science teacher is involved only peripherally, if at all.

The interface between science, technology and society 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 (CSSE 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. It is also interesting to note that these topics are not avoided because of their controversial nature. Teachers seem not to be afraid of such issues and are able to handle them without getting into difficulty. They avoid this controversy by not taking a personal or advocacy position (CSSE 12-28-29). To some extent, the failure of school science to deal with societal issues must surely stem from the schools' insularity; schools which make little attempt to involve members of the community in curriculum and learning or the development of educational goals are not likely to assign a high priority to the inclusion of societal issues in the science syllabus.

Although fundamental scientific knowledge takes second place to the basics such as reading, arithmetic and spelling, as noted previously, it is clear that fundamental knowledge takes precedence over the other three goal clusters. The focus of 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. The curriculum is "text-bound", but many texts show the influence of the NSF-supported curriculum reform movement of the 1960's. Teachers have a wealth of good materials to choose from in teaching the fundamental knowledge of the science discipline.

As with personal needs and societal issues, career preparation is not given high priority in the science curriculum. While vocational reasons for taking science are often cited, it also appears that this rationale has not substantially affected the curriculum. Science is assumed to be important for career preparation, but career preparation is not built into the program. References to career options or sources of career information are rarely found in textbooks or course syllabi. "Science education aims to prepare youngsters for work - or at least for vocational training. For this aim, science is often closely identified with technology. The preparation ethic . . . is pertinent to what is said. . . . There was a strong sense that what mattered most was what could be used in one's next studies, and that those, or the one after those, were related to what one would be doing on the job" (CSSE 12:22).

#### Student Outcomes

The major source of information on student outcomes is that contained in the reports of the National Assessment for Educational Progress. 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 IV is reflected in the student outcomes as measured by the NAEP Science Assessment. For instance: (a) only about 20% 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 ranks last in popularity behind the other three basic academic areas: mathematics, english, and social studies.

Test results indicate that girls do not achieve as well in science as boys do, and the CSSE study goes on to note that "social influences, primarily sex-role socialization, seem to be the basic factors underlying sex differences in science and mathematics achievement and "course taking" (CSSE 15:36). It should also be noted that the performance of ethnic minority students is not as high as others'.

With respect to measurement of student outcomes, another fact is of interest. In states with minimal competency testing programs, science often is not included (OSU 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 characterized 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 (RTI 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 CSSE study 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" (CSSE 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 (CSSE 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 CSSE 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'" (CSSE 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" (RTI 79-85, 97). Many teachers feel a need for assistance in implementing inquiry/discovery approaches (RTI 148).

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 privileged 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" (CSSE 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" (CSSE 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 (CSSE 12:42). Environmental concepts, societal concerns, interdisciplinary relationships and world problems are emphasized in a variety of courses that have been developed (OSU 30). Both the number of alternative materials available and enrollments in such courses have been on the increase (OSU 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 (CSSE 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 . . . " (CSSE 13:63). Laboratory exercises, where used, tend to be just that - exercises - rather than explorations 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 (OSU 30). It was noted in the

CSSE study 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 (RTI 103).

With respect to individualized and self-paced instruction it appears that a very small number of students receive this mode of instruction in spite of the efforts that have been made to promote their use in recent years (OSU 35). Audio-tutorial or videotape courses were not mentioned by any observers in the CSSE 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 (CSSE 13:7). Approximately half of the science teachers view this as at least "somewhat of a problem" (RTI 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 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 result of the sample analyses 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 16mm 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 Dissemination

Information about new materials and programs are disseminated through a wide variety of means. The popular sources include professional meetings, journals, publishers' representatives, teachers, principals, courses and NSF institutes. Other teachers and college courses are the most frequently used sources and local inservice programs are reported to be useful sources by elementary teachers but not by secondary teachers. About half of grades 10-12 teachers, one-third of grades 7-9 science teachers, and 80% of state science supervisors indicated they had participated in an NSF institute. Teachers who had participated in NSF institutes recalled them with much pleasure and believed them to be of considerable value (RTI 71-76).

In spite of the wide variety of means of dissemination, teachers' perceptions are that their needs are not completely met in this regard. At all grade levels the list of their needs is headed by "learning new teaching methods" and "obtaining information about instructional materials" (RTI B-106-115). Forty-three percent of teachers indicated they do not receive adequate assistance in obtaining information about instructional materials (RTI 148).

#### 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 (RTI 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 (CSSE 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" (CSSE). 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" (CSSE 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 with their corresponding demands for innovation, efficiency and performance incentives, few are motivated to explore alternative course options in trial settings.

It is also apparent that there are some obvious conflicts between the norms or expectations of teachers and people who work outside the classroom setting. For example, it was noted that "teachers and supervisors emphasize different purposes and values" (CSSE 16:43). A similar conflict is noted between teachers and college personnel. "It was clear to us that the school had a set of social norms (ways students were supposed to behave) which conflicted with the norms teachers were taught to espouse in teacher training courses. Not only the education courses have dysfunctional norms; the liberal arts norms were substantially the same" (CSSE 16:5). Even though the above conflicts have been noted, and it is clear that the inquiry approach commonly espoused in teacher institutes is now widely accepted, it has also been pointed out "that the (NSF teacher) institutes have been seen to have a good impact . . . Among many federal programs to support curriculum and teaching, the institutes were mentioned to us most often and in a positive vein" (CSSE 16:53).

A final matter of note here is that teachers seem to view universities as having a potentially useful role in developing curricular materials. When asked what universities could do to most help teachers, junior high school science teachers chose the option "develop curriculum more appropriate to the time" much more often than any of the other options which included conducting inservice workshops, offering courses for teachers, establishing teacher centers and sponsoring mutually supportive teacher networks.

### Program Implementation

#### Exposure

The actual implementation of science programs in the schools is best described in terms of course offerings, enrollments and materials utilized. Of the many textbooks available for use in science classes, a relatively small proportion constitutes the majority of books actually in use. Thus, the programs implemented are characterized by a few of the well-known textbooks. In terms of the curriculum reforms in science education of the last couple of decades, the degree to which they have met their goals in terms of implementation in the schools is still a subject of debate (OSU 105). In view of the previous information presented about the manner in which courses are taught and the degree of uniformity among textbooks in terms of the relative emphasis upon the four goal clusters, however, a fairly clear picture of science program implementation can be obtained by looking at the enrollments in various courses.

While the data indicate that the percentage of students taking science courses both in grades 7 - 9 and in grades 10 - 12 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 (OSU 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 (OSU 29).

With respect to physical science, several enrollment trends are of interest. Enrollments in general science-type 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 (OSU 71). For a large percentage of students the last physical science course they get is in the 9th grade. About 50% of secondary school

students complete their last science course in the 10th grade, but in the vast majority of cases this is biology (OSU 36-37).

### Teachers

The Case Studies (CSSE) 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 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 (CSSE 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 on attention because of its intrinsic value becomes a matter of secondary importance (CSSE 16:7).

"We saw the science teacher working conceptually as influenced by three poles: (1) the ethic of scientific inquiry; (2) the 'ideal' science teacher role; (3) socialization responsibilities" (CSSE 16:7). As a result of these three poles and the fact that these teachers did not give them the same relative importance as science education specialists and curriculum specialists, we have the conflict cited earlier (CSSE 16:8).

Thorough examination of the CSSE 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 outlook that teachers and the best school personnel have about educational objectives and practices (CSSE 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 (CSSE 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 (CSSE 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 (CSSE 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 (CSSE 16:24).

Given this view of who teachers are and the outlook on the system within which they work, it is relevant to consider the modes of professional development available to them and the extent to which they are utilized. It was found that the "teacher is engaged in occasional staff meetings, a diminished program of inservice training and some continue to enroll in university courses . . . ." But, ". . . continuing professional education activities were meager" (CSSE 16:48). It is also relevant to note that by and large teachers worked alone. In addition, teachers indicated that they read an average of seven articles and four books of a professional nature each year. The authors of the CSSE study claim that the impact of this reading on their teaching is not extensive (CSSE 12:7).

Teachers are not convinced that the "system" is very supportive of them. They do not praise college-level courses, they feel frustrated with student motivation, and feel unsupported in terms of pay, budget, and recognition.

In addition to this information on teachers' attitudes and general outlook regarding education, students and the system of which they are part, it is important to identify some of the more tangible information about their preparation for the jobs they hold. Their preparation, and the organizational structure within which they utilize this preparation, are relevant.

From grade 4 to 8 the percentage of instruction offered by special science teachers increases with grade level. At the secondary level science is taught mostly in departmentalized subject areas. While some team-teaching situations exist, the great majority of science teaching is offered by teachers in single teaching situations (OSU 14).

In terms of their preparation, it should be noted that elementary school teachers rarely are required to take more science content in their undergraduate programs than that required of them in the general education component. Certification for secondary school science teaching, on the other hand, usually requires a minimum of 24-36 semester hours of science (OSU 50). When junior high school science teachers are considered as a separate sub-group of secondary school science teachers, these people (on the whole) have science backgrounds limited to only one area of science. Yet, many fill general science teaching assignments (OSU 71). General science teachers have backgrounds either in biology or physical science, but relatively few have experience in more than one area. Earth science teachers had the least preparation in their major teaching area. The majority of both chemistry and physics teachers had reasonable preparation in their particular field.

Given the above picture of science teachers, it is apparent that their attitudes toward education, and in particular the educational goals to which they give importance in practice, are of major importance. Considering the important role of teachers, their view of educational process and educational institutions, and the mechanisms currently in place to cause changes in teachers, it is apparent that bringing about change in science is not easy and any attempts to do so much give major attention to this extant situation.

#### 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 CSSE study 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 (CSSE 15:6-7).

While adequacy of science facilities is perceived as one of the most important conditions necessary to a good science program (OSU 38), and approximately 25% of teachers sampled in the RTI 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 pressures 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.

Little imaginative use is made of media in American science classrooms if the Case Studies schools are typical. Aside from the showing of an occasional 16mm film, use of the overhead projector and perhaps a filmstrip, the classes described do not appear to be particularly modern. Few of the Case Studies reported the use of any techniques which involve contemporary technological advances.

Another matter that can be noted with respect to classroom practices is the extensive use of testing in the schools, which is accepted as a very natural part of the school setting (CSSE 15:12). On the other hand, it is claimed that teachers

make very little use of the information they acquire by testing (CSSE 15:21). The obvious question then is why teachers are making increasingly greater use of tests. "Although formal testing did not seem to satisfy most of the teachers' need to know what the students knew, testing did seem to assist in socializing students and maintaining control over them" (CSSE 15:23).

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 (CSSE 15:23). Sixty to seventy percent of grades 7-12 teachers felt that "lack of student interest in subject" was at least somewhat of a problem (RTI 158).

Another student characteristic that poses a learning difficulty as perceived by teachers is poor reading ability. Seventy to eighty percent of teachers, grades 4-12, feel that "inadequate student reading abilities" is a moderate to serious problem (RTI 158). It is reported that 40-44% of secondary principals agree with teachers about reading problems, but few perceive lack of student interest as a problem in science (RTI 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 an important positive contribution to motivating the academically able student (CSSE 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 are somewhat interested in grades, is substantiated by data other than reported in these studies (CSSE 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 13- and 17-year olds indicated that they "often" to "sometimes" use scientific approaches when solving problems outside of science 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 science 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 insight 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 (OSU 35). The average student gets no physical science in senior high school.

#### Evaluation

Attention to accountability is on the increase and the assumption that it is of value for schools is not being challenged (CSSE 17:10). This movement toward accountability is reflected in minimum competency tests, criteria-referenced diagnostic tests and standardized achievement tests. "We found no actual evidence of the validity of these accountability procedures. But, neither teachers nor technical people at the district were seen to be raising questions about validity" (CSSE 17:11). It also is interesting to note that even though these approaches to accountability emphasize objective measures of student performance, most expressions of the performance of the schools were in terms which reflected the reasons why the schools were supported by the community (CSSE 17:11).

The testing employed in schools include both teacher-made tests which are used quite frequently and standardized tests administered by the district. Science standardized tests were used in 43% of the K-6 schools and 33% of the 7-12 schools (RTI 27-37). The most frequently reported use of the results of the standardized science tests was for reporting results to teacher and parents. The moderate use in revising curricula and planning inservice education was noted mainly at the K-6 level (RTI 200-202).

Even though evaluation as described here was valued, there were reservations about the cost of it in terms of instructional time. "Many teachers spoke highly of the increased manageability of instruction through objectivication but objected to instructional time diminished by time taken by testing and were apprehensive about what might be done outside the classroom with the test scores" (CSSE).

Summary

The overall impression that one receives from the four studies is mixed. Clearly, there are many worthwhile things taking place in school science even as support for science in curriculum declines. On the other hand, an examination of contemporary school science in terms of the four broad goal clusters suggests that much of what is taking place does not address the needs and interests of the majority of American youth.

## Recommendations for Physical Science Education

### Introduction

The recommendations made in this section of the report are an outgrowth of the analyses reported upon in the preceding sections and summarized again below. The process of formulating recommendations is one of logical analysis of the discrepancies between the various desired states and actual states of physical science education programs. Any attempt to identify such discrepancies, however, requires that value judgments be made. In describing desired states, such value judgments were avoided as much as possible, and the descriptive framework developed was intended to make allowance for whatever set of values a particular individual might bring to the situation. At this point, however, value judgments cannot be entirely avoided. When they are necessary, they will be made as explicit as possible.

The recommendations presented here reflect not only the value judgments of the members of the physical science focus group but also their thorough knowledge of the four studies under consideration, as well as knowledge of the state of physical science education today based on their own experience. Working as a group, they engaged in extensive discussion during a series of four three-day sessions in which they compiled their individual work, reacted to the input of the supervisory group and developed their various reports including the recommendations contained herein.

### Summary of Desired States

The purpose of describing "desired states" was to develop a conceptual framework for synthesizing the results of the four major research studies and formulating the recommendations which would grow out of them. This conceptual framework consisted of a set of goal clusters, physical science themes and critical elements in the educational setting. For purposes of the work at hand, a description of the goal clusters is most relevant and is given below.

The wide variety of physical science education goals was placed in four clusters. They are presented below with a few brief and very specific examples of desired student outcomes that may help to convey the meaning of each goal cluster as it pertains to the physical science.

I. Personal Needs. Those goals which pertain to preparing individuals to use science in their own lives and to live in an increasingly technological world.

- 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.~~
- 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.

II. Societal Issues. Those goals which pertain to preparing informed citizens who are able to deal responsibly with science-related issues.

- Comprehend the origins and limitations of the supply of ground water, fossil fuels and mineral resources.
- Comprehend the dangers, potentials and comparative advantages of fusion and fission technologies.
- Recognize that scientific knowledge is changing and thus 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.

III. Fundamental Knowledge. Those goals which pertain to acquiring academic knowledge of science.

- Comprehend, apply, evaluate, and synthesize knowledge of kinetics, dynamics, astrophysics, mechanics of fluids, geophysics, physical geology, weather and climate.
- Comprehend, apply evaluate, analyze and synthesize knowledge of potential and kinetic energy, wave phenomena, sound, light, electromagnetic spectra, static and current electricity, electronics, magnetism and electromagnetism, and solar radiation.

IV. Career Preparation. Those goals which pertain to acquiring knowledge of the nature and scope of scientific and technological careers and the propensity to utilize this knowledge in making a career decision.

- Make appropriate career-related decisions based on competencies in the areas of personal needs, societal issues and fundamental knowledge as stated in the goal clusters above.

These goal clusters will be referred to again in discussing the recommendations found later in this report.

Summary of Actual States

A previous section of this report contains a comprehensive description of the actual state of physical science education in the United States as distilled from the four studies. Although there is a multiplicity of significant findings reported there, three main facets of the extant school situation stand out and are reported here.

First, there is an obvious extensive, and almost exclusive attention to the fundamental knowledge goal cluster with a concomitant inattention to the other goal clusters of personal needs, societal issues and career preparation. While isolated instances of attention to the other three goal clusters can be found, the overall situation is one in which the fundamental knowledge goal cluster is almost completely and exclusively dominant.

Second, the curriculum is textbook-bound. In other words, once a decision has been made as to what textbook will be used in a particular course, the curriculum has been determined, and from that point on any curriculum decisions made are ones of selection from the material in that book. The text is used as the authority and source of information.

Third, but not of least importance, is the key role played by the teacher. The character of the educational experience received by a student in a particular classroom is largely a function of who the teacher is. Although the teacher does not operate in complete isolation, what variations are found from one classroom to another are largely a function of the individual teacher and, more significant yet, what happens in American schools as a whole is largely a reflection of the values held in common by teachers.

The true significance and impact of this key role of the teacher cannot be understood independently of the previous two matters; namely, the almost exclusive attention to the fundamental knowledge goal cluster and the textbook domination of the curriculum. These factors are highly interactive. The goals pursued in physical science classrooms are the ones valued by teachers, and, by and large, they are the same goals that are reflected in the textbooks. Looking further, one sees that teachers clearly are the main influence in choosing the textbooks, even though the decisions are not left entirely in their hands. In addition, teachers value a textbook-oriented approach.

It should also be noted that teachers and other school personnel are responsive to external influences such as the community of which they are a part and the colleges for which they are diligently preparing their students. Although there are some indicators in these four studies of the nature of teachers' responsiveness to these external influences, this matter needs much further attention because it

may be the key to implementing changes in the schools.

### The Key Messages

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 states 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 pursued 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 occurs in the science programs of middle schools. The physical science instruction at this level often is limited by: (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 education 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 recommendations presented in this section are an outgrowth of the analysis of the extant educational situation as described previously. Five 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.

#### Goals and Objectives

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 the 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 all 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.

#### Program Development and Modification

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 of the RTI, CSSE, OSU and NAEP studies. 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 7 - 9 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. There should be an intensified dissemination of existing programs that provide such emphasis.
- (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 9 - 12 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. The dissemination of existing programs having this emphasis should be intensified.
- (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:
  - (a) 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.
  - (b) Opportunities should be provided to apply science processes to real-world problems that have no pat solutions but require compromise and optimization.
  - (c) Personal needs, societal issues and career preparation should be considered intrinsic to all facets of these science programs.
  - (d) Basic concepts of physical science should be dealt with in the context of socially relevant problems.
  - (e) Opportunities should be provided for students to interact with people working in science-related fields.
  - (f) Opportunities should be provided for students to identify with persons of different lifestyles, socio-economic status, ethnicity, and sex who are fully participating in the scientific enterprise.
  - (g) Emphasis should be placed on the means by which scientific knowledge is generated.
  - (h) 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.

## Teacher Education

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. A higher priority for staff development on the part of funding agencies, local school boards and school administrators should be encouraged.
- (2) Incentives should be provided that will encourage teachers to participate in nationally and locally developed inservice education programs and staff development activities. Such incentives might be free tuition (as per the highly successful NSF institute plan), release time, stipends and honoraria.
- (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 level 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. The plan developed and implemented should provide a means for identifying and organizing existing curriculum materials and tailoring existing materials to current curricular modes.
- (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.

## Evaluation

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 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 informed of the results of Project Synthesis and 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) Appropriate articles should be written for test personnel encouraging them to pursue Recommendation #4.
- (4) Banks of appropriate test items should be provided for school district personnel to draw upon in developing their local district accountability procedures.
- (5) Professional science teaching societies should be encouraged to develop or acquire appropriate item banks and encourage their use.
- (6) Established citizen-accountability groups should be informed (through conferences and publications such as a booklet for committee members) of the need in question and encouraged to use their influence to assure that appropriate modifications to tests are made.
- (7) NIE should be encouraged to maintain an assessment of science through NAEP.
- (8) 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.

Research

Recommendation #5. Research should be encouraged in areas that have particular potential for influencing science education practice, and the results should be disseminated to those individuals, groups, organizations and institutions having the potential for placing the relevant findings into practice.

The synthesized results of the four studies not only produce new insights as to future directions for educational practice but raise further questions which if diligently pursued have the potential of benefiting students. Among the specific topics having high priority for research are the following:

- (1) The determination of the effect of science instruction on the development of general cognitive skills such as reasoning, language and mathematics skills.
- (2) The determination of the "real world" outcomes of science instruction (e.g., do people choose careers more wisely, eat more sensibly, avoid hazards, participate in science-related political decisions, and attack problems more effectively?).
- (3) The identification of course offerings which are effective in promoting science achievement in all goal clusters.
- (4) The identification of specific teaching strategies and behaviors relating to physical science achievement, especially as they pertain to the personal needs, societal issues and career awareness goal clusters and as they pertain to students who now take little or no physical science in high school.
- (5) The determination of the relationships between student motivation and (a) the percentage of time (emphasis) on the personal needs, societal issues and career awareness goal clusters, (b) instructional approaches (traditional vs. inquiry approaches), (c) the level of cognitive learning emphasized, and (d) affective learning.

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CHAPTER 8

INQUIRY PHASE I REPORT:  
THE DESIRED STATE OF INQUIRY

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## INQUIRY PHASE I REPORT: THE DESIRED STATE OF INQUIRY

Background

The general process by which human beings seek information or understanding is called inquiry. Broadly conceived, inquiry is a way of thought. Scientific inquiry is the subset of general inquiry that is concerned with the natural world and is guided by certain beliefs and assumptions.

The description of a desired state of affairs for student understanding of inquiry presented in this paper is based in part on earlier writings of Klopfer (1976). In addition, several beliefs guided our interpretation of the inquiry domain. These are listed below:

1. Inquiry as a way of thought is a valuable goal for education.
2. There are certain characteristics of the nature of scientific inquiry that students ought to learn.
3. Scientific inquiry is not a prescribed set of steps, but it does contain some common elements that need to be addressed.
4. Process is pervasive -- it, together with conceptual schemes, is what is likely to remain after the content is forgotten.
5. We recognize and advocate the importance of informed attitudes as an integral part of scientific inquiry. The following statement describes this point of view:

Students will possess informed attitudes toward the process of disciplined inquiry, particularly those processes and knowledge characteristics of scientific inquiry. Indications of the existence of such attitudes will span the continuum from merely being aware of a phenomenon (receiving) to making a concerted effort to respond (organization). For some students, attitudes toward scientific inquiry will become their life outlook (characterization).

Students will exhibit different feelings about different components of the processes of science, but our desire is that students will respond to the process of science with positive feelings (valuing).

In our statements of desired student outcomes we have chosen to weave affective (feeling) statements in with our cognitive (knowing) and skill (doing) statements.

6. We recognize that all possible desired student elements could not be covered in a document such as this. Therefore, we have sampled the domain of inquiry selecting those aspects that are most important and presented examples of these across the four goal clusters.
7. The student outcomes are pitched at the able high school graduate, but we expect a range of competencies.
8. Some student outcome statements represent minimal outcomes. The other student outcome statements relate to those students who take two or more science classes in high school. As usual, the intellectual development and interests of the students must influence the extent to which the non-minimal outcomes are met.

## Domain of Inquiry

The set of elements associated with the term "inquiry" has been divided into three main themes and nine subthemes. These are presented in order of increasing complexity and abstraction. Brief descriptive phrases are used to elaborate the subthemes where necessary.

### I. Processes or Methods of Science

#### A. Observing and Measuring

#### B. Seeing a Problem and Seeking Solutions

This process refers to that rather difficult task of recognizing or choosing problems and then through a combination of hard work, thought, skill, past experience, or just plain luck, finding solutions to the problems. Also involved are such things as problem recognition, developing hypotheses and testing hypotheses, often through experiments.

#### C. Interpreting Data and Forming Generalizations

#### D. Building, Testing and Revising a Theoretical Model

Theoretical models are viewed as conceptual schemes that allow us to "understand" a variety of phenomena in the natural world. Good models are broadly generalizeable and can be used to generate predictions to be tested. They indicate how observations and concepts are related.

### II. Nature of Scientific Inquiry

#### A. Scientific Knowledge as a Product of Scientific Inquiry

Scientific knowledge consists of ideas about natural phenomena in the form of observations, laws, hypotheses, theories, models and assumptions. This knowledge is tentative. It is the product of human effort. Science knowledge and the direction of inquiry itself is affected by a number of psychological and sociological influences, such as, the social context in which the scientific inquiry occurs. It comprises the assumptions and metaphors of those who created it, those whose principal aim was to satisfy their curiosity about natural phenomena. Thus, there are limitations to scientific knowledge and scientific inquiry -- limitations related to psychological and sociological effects and limitations possibly bounded within the domain of natural phenomena.

There are some basic assumptions in scientific inquiry which have endured over a long period of time. These assumptions about the natural world include causality, noncapriciousness and intelligibility.

#### B. The Diversity of Tactics and Strategies in Scientific Inquiry

While different branches of science share similar types of inquiry, there are as many different "scientific methods" as there are scientists.

However, two modes of inquiry are often recognizable: (a) stable inquiry-- inquiry proceeding within the accepted scientific knowledge of that area; (b) fluid inquiry -- inquiry that challenges, and perhaps alters, the theoretical structure of the discipline.

#### C. The Self-testing and Empirical Aspects of Scientific Inquiry

Scientific knowledge raises questions about phenomena. In an attempt to answer these questions, scientists create hypotheses. Scientists test these hypotheses by means of independent empirical verification. Observations are gathered by different people under experimental conditions, and then these observations are compared with predictions deduced from the original hypothesis. The observations used to verify or falsify the hypothesis are: (a) contingent upon the experimental conditions and the instruments used to gather the data and (b) judged true if they are based on sense data, repeatable by anyone trained in inquiry techniques. Theories are useful ("true") to the extent to which scientists believe in the confirming observations. Criteria for accepting a theory include such things as logical coherence, simplicity, explanatory power, predictive power and potential for growth in developing scientific knowledge. Theories guide observations. Disconfirming observations may lead to modification, restriction in the scope of application or replacement of the theory.

### III. Inquiry As A Way of Thought

#### A. Strategies of Inquiry

##### 1. Generation and selection of appropriate problem-solving strategies.

Is it a values (or values-related) question? If yes, use values-

clarification strategies. (For example, see Values and Teaching by Raths, Harmin and Simon.) Is the aim to develop scientific knowledge and understanding? If yes, use strategies detailed in "Processes of Scientific Inquiry." Is the purpose (need) to apply knowledge, skills and/or procedures to a personal or engineering-type problem? If yes, use general problem-solving strategies. (For example, see How We Think by J. Dewey or Critical Thinking by M. Black.) Is the purpose (need) to decide among alternative societal actions to be taken? If yes, use decision-making strategies. (For example, see Developing Decision-Making Skills by D. Kurfman.)

NOTE: Whichever set of strategies is selected, all the considerations discussed under Evidence, Reasoning, Safeguards and Customs apply.

## 2. Evidence

Includes questions of relevance, usefulness, judging reliability and utilizing evidence to make decisions.

## 3. Reasoning

Includes logical reasoning, analogical reasoning, assumptions, causality, multiple-causality and judging alternatives.

NOTE: Consideration also must be given here to alternative systems of logic -- especially the logic systems of children (and adults?) who have not attained the Piagetian formal operations stage.

## B. Safeguards and Customs of Inquiry

These are the generally agreed-upon procedures, operating modes or rules of the game (the "ethos") that individuals participating in all forms of rational inquiry are expected to follow. Some of the more important procedures include open-mindedness; criticalness, including of one's self; commitment to accuracy; integrity; and sharing through public discussion seminars and written reports.

Desired State For Critical Elements

Desired Student Outcomes

Goal Cluster I: Personal Needs.

Observing and Measuring

- \*1. (Doing). Measures accurately those body symptoms e.g., blood pressure, heartbeat, temperature, etc., that are important in monitoring one's health.
- \*2. (Doing). Observes and measures those consumer products to be purchased to guard against fraud, deception or exorbitant costs.
- \*3. (Doing).. Observes and responds to phenomena in his/her environment in order to insure personal safety.

Seeing a Problem and Seeking Solutions

- \*1. (Knowing). Is able to form and test hypotheses around problems related to personal needs and interests, e.g., acne, over-weight, low grades, autos that won't start and water in the basement.
- \*2. (Doing). Could design and carry out an experiment to test a problem related to a personal need; for example, which brand of peanuts contains the most oil, or do expensive gasoline brands yield better mileage than cheaper ones?

Interpreting Data and Forming Generalizations

- \*1. (Doing). Is able to understand critical data presented in graphs and tables in daily newspapers and magazines.
- \*2. (Doing). Can record and present data on some bodily function, e.g., daily temperature fluctuations as an indication of fertility.
- \*3. (Doing). Can judge the appropriateness of a tested hypothesis in solving a personal problem, on the basis of data obtained; e.g., cost of gasoline and mileage rates.

\*minimal outcomes

### Building, Testing, and Revising a Theoretical Model

1. (Attitude). Realize that the possession of a few broadly encompassing models will assist in interpretations of and attitudes toward the environment. Examples include justice/fairness, socio-biology, evolution, compromise and democracy.

### Scientific Knowledge as a Product of Scientific Inquiry

1. (Doing). Discusses media reports about scientific findings:
  - (a) appropriately using the terms: observations, laws, hypotheses, theories, models and assumptions;
  - (b) expressing the tentativeness of the findings and
  - (c) acknowledging the role of the human mind and imagination in those findings.
- \*2. (Doing). Classifies statements as being within or outside the realm of science.
- \*3. (Knowing). Deliberately recognizes that the relevance of scientific knowledge is likely 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.

### The Diversity of Tactics and Strategies in Scientific Inquiry

- \*1. (Knowing). Does NOT have faith in following a stepwise description of the "scientific method" as a way to solve problems.

### The Self-testing and Empirical Aspects of Scientific Inquiry

1. (Knowing). Views the "truth" of scientific theory in terms of its usefulness for explaining, predicting or encouraging growth in science.
- \*2. (Attitude). When engaged in scientific inquiry, values the empirical verification basis of science.

### Strategies of Inquiry

1. (Attitude). Enjoys the challenge of refining problematic situations into solvable problems.
2. (Knowing). Can judge whether a problem has been identified.
- \*3. (Knowing). Can ask questions to determine what the problem to be solved is.

- \*4. (Knowing). Realizes that it is necessary to determine the extent of the reliability of certain new evidence which shows that there is no connection between cigarette-smoking and lung cancer in humans.
- \*5. (Doing). Identifies the source of certain new evidence concerning the connection between smoking and lung cancer as the Tobacco Institute (a research organization sponsored by the tobacco industry).
- \*6. (Doing). Identifies the source of certain new evidence concerning the connection between smoking and lung cancer as a university research study sponsored by the U. S. Public Health Services.
- 7. (Doing). Studies the research report containing new evidence concerning the connection between smoking and lung cancer to find out the conditions under which the study was carried out.
- 8. (Doing). Uses evidence from a variety of sources to make decisions about personal health problems.
- 9. (Knowing). Can apply rules of "if-then" reasoning to personal problems such that (1) acceptance of the "if-part" requires acceptance of the "then-part", but not necessarily vice versa, and (2) denial of the "then-part", requires denial of the "if-part", but not necessarily vice versa.

#### Safeguards and Customs of Inquiry

- \*1. (Knowing). Accepts open-mindedness as a prerequisite to successful inquiry.
- 2. (Doing). Accepts criticism of the outcomes of one's own problem-solving activities.
- \*3. (Doing). Expresses skepticism about the effectiveness of untested remedies and procedures (e.g., fad diets) concerning one's personal health.
- \*4. (Attitude). Demands to see corroborating evidence to support claims of the effectiveness of substance X in curing cancer.
- \*5. (Attitude). Is committed to accuracy in reporting the outcomes of laboratory investigations in science classes.

#### Goal Cluster II: Societal Issues.

##### Observing and Measuring

- \*1. (Doing). Can measure personal actions that have influence on

society, e.g., monitors through measuring techniques the heat loss of a home.

- \*2. (Doing). Observes the impact of his/her actions on the rest of society, both those that are negative (noise pollution), and those that are positive (not smoking in a crowded room).

#### Seeing a Problem and Seeking Solutions

- \*1. (Knowing). Able to recognize problems of society such as over-population, pollution, venereal disease and lung cancer.
- \*2. (Doing). Can design and carry out actual mini-experiments to test hypotheses about the various problems of society, e.g., water and air pollution.
- \*3. (Attitude). Is supportive of the allocation of public funds for use in solving the science-related problems of society.

#### Interpreting Data and Forming Generalizations

- \*1. (Doing). Can interpret data presented about a societal problem and judge its implications for personal behavior; e.g., the relationship of limiting speeds to 55 mph to resulting gas usage.

#### Building, Testing, and Revising a Theoretical Model

- 1. (Knowing). Several models are proposed as accounting for social behavior. Insofar as these are adequate, it seems important that students are familiar with them. Some examples include justice/fairness, socio-biology, evolution, compromise and democracy.

#### Scientific Knowledge as a Product of Scientific Inquiry

- 1. (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 latered knowledge.
- 2. (Doing). Abstracts from a societal issue the component related to natural phenomena, identifying this component as being germane to scientific knowledge and scientific inquiry.
- \*3. (Attitude). Expresses a view that the support of the scientific enterprise, if it is to take place at all, must take place in the form of support of human needs (those of the scientists).
- \*4. (Knowing). Consciously acknowledges that the fundamental driving

force of a scientist doing inquiry likely emerges from his or her curiosity about natural phenomena, rather than from his or her involvement in a societal issue.

The Diversity of Tactics and Strategies in Scientific Inquiry

- 1. (Attitude). Accepts or anticipates that the science component of a societal issue can give rise to different solutions.

The Self-testing and Empirical Aspects of Scientific Inquiry

- 1. (Knowing). Recognizes that scientific theories (which relate to a societal issue) are considered useful in the realm of science, however, they may not necessarily be considered useful in terms of societal issues.
- \*2. (Attitude). Does not expect scientists to use knowledge in their scientific thinking unless it has been verified empirically by independent groups.

Strategies of Inquiry

- 1. (Knowing). Is sensitive to the importance of making decisions about selecting the appropriate strategies for solving science-related societal problems.
- 2. (Attitude). Has faith in the power of reason and in systemic approaches to problem-solving for science-related social problems.
- \*3. (Knowing). Can decide what the main issues of a simple science-related social problem are.
- \*4. (Knowing). Can decide what is and what is not scientific evidence in a simple science-related social issue.
- 5. (Doing). Identifies evidence from prepared sources (i.e., newspaper and magazine articles), that relate to decisions for science-related social problems.
- 6. (Attitude). Enjoys identifying the evidence needed for decision-making about science-related social issues.
- 7. (Attitude). Consistently seeks out information to determine the extent of the reliability of evidence concerning the expected depletion of fossil fuels and the shortages of other energy resources.
- 8. (Doing). Identifies two or more possible decision alternatives for science-related social issues.
- 9. (Doing). Evaluates the consequences of each alternative in a decision-making situation for science-related social issues.



## Safeguards and Customs of Inquiry

1. (Doing). Searches out alternative ways of possibly getting to the major goal in a science-related social issue.
- \*2. (Knowing). Acknowledges the desirability of considering various alternative viewpoints concerning science-related social issues.
3. (Doing). Considers the arguments of persons who hold viewpoints different from his/her own concerning solutions to the energy crisis.
4. (Attitude). Consistently insists on giving opportunities to be heard to proponents of various viewpoints concerning water and air pollution issues.
5. (Doing). Revises conclusions or opinions about science-related social issues in the light of new reliable evidence.
6. (Attitude). Deliberately examines a variety of viewpoints on various environmental issues in the process of forming opinions about them.
7. (Doing). Compares the adequacy and reasonableness of several proposed solutions to the problem of the growth of the human population.
8. (Doing). Suspends judgment on a proposed solution to a science-related social issue when insufficient evidence is presented.
9. (Attitude). Takes pains to clearly and consistently distinguish between observations and empirical data (on the one hand) and interpretations of observations and causal inferences or explanations (on the other hand) when discussing the results of an investigation of a science-related social problem.
10. (Attitude). Consistently calls attention to the need to obtain accurate and reliable data on the potential environmental risks of building a new nuclear power plant.
11. (Doing). Changes one's opinion about controversial issues concerning the environment when a reexamination of the evidence warrants a revised opinion.

12. (Attitude). Consistently employs only reliable evidence, rather than propaganda, to support his/her viewpoint on a science-related social issue.

### Goal Cluster III: Fundamental Knowledge.

#### Observing and Measuring

- \*1. (Doing). Is able to observe and describe objects and phenomena (including change) using appropriate language.
- \*2. (Knowing). Can list or identify differences and similarities among two or more objects.
- \*3. (Doing). Uses the tools a scientist uses to improve his observational capacity (e.g., microscope, telescope, camera).
- \*4. (Knowing). Is able to measure objects and events by selecting appropriate measuring instruments.
- \*5. (Doing). Estimates measurement with relative (appropriate) accuracy.
- \*6. (Knowing). Knows the precision (errors) in a given statement.

#### Seeing a Problem and Seeking Solutions

- \*1. (Knowing). Can recognize and select problems.
- \*2. (Doing). Formulates working hypotheses.
- \*3. (Knowing). Can select tests suitable for various hypotheses.
- \*4. (Doing). Designs and conducts experimental tests of hypotheses.
- \*5. (Knowing). Recognizes that problem selection and hypothesis formation are sometimes accomplished in direct and programmed ways, and other times they are very much unpredictable processes. In both cases, however, they involve intelligence and patient, hard work, though neither guarantees success.

#### Interpreting Data and Forming Generalizations

- \*1. (Doing). Can process (e.g., record, list, summarize, etc.) data from experiments and observations.
- \*2. (Attitude). Sees value in presenting data in the form of functional relationships, e.g., tables, graphs, equations.

- \*3. (Knowing). Can interpret patterns and trends of experimental data and observations.
- \*4. (Knowing). Is able to carry out the processes of extrapolation and interpolation and understands the limitations of these processes.
- \*5. (Doing). Can evaluate the hypothesis tested on the basis of data obtained.
- 6. (Doing). Can formulate generalizations appropriate to relationships among data obtained in experiments, e.g., the longer the pendulum, the larger the period.

#### Building, Testing, and Revising a Theoretical Model

- \*1. (Attitude). Recognizes need for theoretical models to relate different phenomena and principles.
- 2. (Doing). Can formulate a theoretical model in the various science content areas.
- 3. (Knowing). Can specify which phenomena and principles are included in a model.
- 4. (Doing). Deduces new hypotheses from an existing theory.
- 5. (Knowing). Can evaluate results of experiences to test a theoretical model.
- 6. (Knowing). Can refute or revise a proposed model on the basis of experimental observations or interpretations.

#### Scientific Knowledge as a Product of Scientific Inquiry

- 1. (Knowing). Recognizes examples of the following types of scientific knowledge: observations, laws, hypotheses, theories, models and assumptions.
- \*2. (Doing). Cites examples of earlier and current scientific explanations which have been, or are being, altered.
- \*3. (Attitude). Expresses the view that the students' science textbook will need to be rewritten by the time their children study science (in order to revise laws, hypotheses, theories and models contained in that text).
- \*4. (Doing). Describes human characteristics which facilitate the growth of scientific knowledge.

### The Diversity of Tactics and Strategies in Scientific Inquiry

- \*1. (Doing). Describes examples of stable and fluid inquiry which the student has experienced in science classes and which are being carried out in science at the present time.
- \*2. (Attitude). Expresses the view that different scientists may use different methods of inquiry because of individual differences among scientists.

### The Self-testing and Empirical Aspects of Scientific Inquiry

- \*1. (Knowing). Recognizes instances of independent empirical verification.
- \*2. (Knowing). Cites independent empirical verification as a basic criterion for judging the "truth" of scientific statements.
- \*3. (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.
- 4. (Doing). Cites examples of theories or models which are used in science today in spite of their having some inaccuracies.
- \*5. (Attitude). Expects theories to be altered, restricted, or replaced, in the light of conflicting observations.

### Strategies of Inquiry

- \*1. (Knowing). Can grasp the meaning of simple scientific statements and recognize them as being evidence for or against some conclusion. (Example: knows that the statement, "Wood floats in water" implies that "wood is lighter than water" and "whatever is lighter than water floats on it.")
- 2. (Doing). Judges whether an inductive generalization based upon a laboratory experiment is warranted.
- 3. (Knowing). Can judge whether proposed alternative courses of action are adequate, such that the alternatives are likely to facilitate achievement of the decision goal, within the limits of existing resources and goals.

### Safeguards and Customs of Inquiry

- 1. (Attitude). Voluntarily seeks the criticism of others on the data and interpretations of his/her experiments.

2. (Doing). Designs an experiment to test a certain hypothesis which is contrary to the hypothesis he/she believes to be correct.
3. (Doing). Accepts the disagreement of scientists about interpretations of the outcomes of scientific research.
4. (Doing). Designs a new experiment to again test a hypothesis which he/she already found to be correct in several previous experiments.
5. (Doing). Identifies logical flaws in the interpretations of observations in an experiment.
- \*6. (Attitude). Is committed to the necessity of accuracy in the work of scientists.
- \*7. (Doing). Records all data which he/she observes in experiments and only data which he/she observes.
8. (Attitude). Takes pride in the accuracy of data he/she collects in experiments.
9. (Attitude). Prefers statements about experimental findings which are precise and coherent, rather than imprecise and incoherent.
10. (Knowing). Is aware or accepts the proposition that scientific progress resides in the integrity of scientists.
11. (Knowing). Accepts the valuing of freedom of inquiry as a necessity for scientific investigation.
12. (Attitude). Consistently avoids making too great an exaggeration of the significance of findings in an investigation he/she has carried out.
- \*13. (Doing). Never fails to report the complete set of observations in an investigation, rather than leaving out cases unfavorable to his/her hypothesis.

14. (Knowing). Is aware that science is a social phenomenon and progresses through publication and discussion of the findings of scientific work.
15. (Doing). Participates in communicating the results of his/her outcomes in the solution of scientific problems.

Goal Cluster IV: Career Education and Preparation.

Observing and Measuring

- \*1. (Doing). Participates in a variety of observational and measurement activities to sufficiently examine the potential and interest to them for a career in science.

Seeing a Problem and Seeking Solutions

- \*1. (Attitude). Enjoys involvement in opportunities to participate in science-related problem identification and solutions.

Interpreting Data and Forming Generalizations

1. (Doing). Has sufficient training in data interpretation to be able to continue the training sequence if interested.
2. (Doing). Has experienced the successes and problems of interpreting data and forming generalizations to realistically consider careers in science.

Building, Testing, and Revising a Theoretical Model

- \*1. (Attitude). Involved in the process of building, testing, and revising theoretical models to such an extent to be able to judge interest and competency in the process and can judge potential as future scientists and engineers.
- \*2. (Attitude). Appreciates the value of models in understanding natural phenomena and is interested in pursuing careers that use such approaches.

Scientific Knowledge as a Product of Scientific Inquiry

1. (Knowing). Recognizes the primary need to be curious about natural phenomena in order to be suitable for a science vocation.

2. (Knowing). Recognizes the latitude in science for expressing human ingenuity and creativeness.

#### The Diversity of Tactics and Strategies in Scientific Inquiry

1. (Knowing). Recognizes that a career in science does not require a singular role, but is open to a number of different roles.

#### The Self-testing and Empirical Aspects of Scientific Inquiry

(Empty set)

#### Strategies of Inquiry

- \*1. (Doing). Decides what the main issues of selecting a science career are.
2. (Doing). Identifies the sources of conflicting evidence dealing with the representation of women scientists in various science fields.

#### Safeguards and Customs of Inquiry

1. (Doing). Values open-mindedness in those who pursue scientific careers.

#### Desired Program Characteristics

1. Requires an explicit statement of desired outcomes.  
(See preceding lists to determine which are needed for each goal cluster.)
2. Should include assessment/evaluation procedures.
3. Should have provision for student involvement in kinds of experiences appropriate to attain desired outcomes, e.g., lab or real world opportunities in the personal, social, knowledge and career clusters.
4. Should be made available to everyone remembering the match of activities of programs to abilities, skills and cognitive abilities of learners.

5. Present content consistent with the desired student outcomes.
6. Should give attention to development of attitudes and examination of values.
7. Could utilize the history of scientific development as a vehicle for promoting the understanding of science processes.

#### Program Dissemination/Adoption - Desired States

The group believes that these elements are of a general nature and have no special uniqueness for the inquiry group. The Synthesis Group should look to the several models of dissemination and utilization in considering this element (e.g., Havelock, Hall, Rogers, Guba and Clark).

#### Program Implementation - Desired States

##### Exposure.

1. Process/inquiry should be included in all science courses.
2. Provisions should be made for early, repetitious exposure to inquiry which continues through schooling and beyond and is "matched" to student characteristics.
3. Science programs must provide opportunities for "process" exposures to students at all ages.
4. Content and process are inseparable -- the issue is not so much "time" but, rather, how it is done.
5. All students should be enrolled in "process-oriented" classes, but the "match" problem must be addressed; i.e., appropriate experiences for differing student characteristics and stages of development.

##### Teacher Characteristics.

1. Possess inquiry skills and value inquiry.
2. Possess teaching skills to encourage inquiry skills in others; e.g., discussion leader.
3. Will model inquiry processes in a variety of problems (e.g., personal, social, discipline, career) some of which may lead to value questioning.

4. Will admit to errors or lack of knowledge.
5. Trained by being involved in inquiry, especially in-service opportunities.
6. Will have had a course in applied philosophy of science; has done an inquiry problem.

#### Classroom Practices.

1. The atmosphere of a classroom should be conducive to inquiry
  - a. "Easy" for students to ask questions
  - b. Risk-taking is encouraged -- students are provided with support for inquiry
  - c. Opportunities for "hands on" experiences
  - d. Physical arrangement of classroom
  - e. "Science objects" and events are present
  - f. Ratio of student talk to teacher talk is high
2. A variety of classroom practices (lecture, drill, etc.) are appropriate in inquiry classrooms at different times; i.e., know there is a time for doing . . . a time for knowing . . . a time for feeling.
3. Self-initiated inquiry should be encouraged.
4. Person-society-discipline-career inquiry topics are used in class.

#### Student Characteristics.

How well-matched are the desired student outcomes of the program with the known characteristics (intellectual, demographic) of the population?

#### Evaluation - Desired States

The group believes that this element is of a general nature and has no unique relevance for the inquiry group. A few things of general concern are listed:

1. Constant formative evaluation is provided for in effective science programs.
2. Continued improvement of evaluation techniques based on current research findings.
3. Is the curriculum appropriate for the student population; e.g., student perceptions?

4. Adequate evaluation processes should be used.
5. Constant evaluation of the appropriateness of program goals is essential.
6. Different evaluation techniques and instruments should be used.
7. Assess the extent to which desired states have been achieved.
8. Identify discrepancies between actual and desired states.
9. Student evaluation techniques should reflect the various goal clusters as an indication of their emphasis or existence.
10. National and state assessments will reflect all goal clusters.

CHAPTER 9

PHASE II INQUIRY REPORT:  
THE STATUS OF INQUIRY IN SCIENCE EDUCATION

Inquiry Group Members:

Wayne Welch, Chairman  
Leo Klopfer  
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Preface

The Inquiry Group found it helpful to consider the status of science education from a slightly different point of view than that reflected by our original list of critical elements. The components of our revised structure are context (potential), transactions (kinetics) and student outcomes (work). The analogy that comes to mind for the structure is the potential energy, kinetic energy, work done triad of physical science. The context for learning science corresponds to potential energy. It refers to the potential ability of the system to accomplish learning and includes the critical elements of objectives, program characteristics, program dissemination/adoption and aspects of exposure to science, teacher and student characteristics formerly under the heading of program implementation. Transactions (including most of the elements of program implementation and evaluation) are the kinetics of the system which lead to certain student outcomes - work done.

Dr. Norris Harms substituted for Dr. James Robinson for much of the Phase II work.

### Context

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, (e.g., the preparation ethic, views of the nature of science, etc.). The purpose of this section is to identify some of the contextual factors which especially affect "inquiry" learning.

#### Values About Science

One important factor which affects the amount of inquiry teaching is the 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 recognize the need for minimal competency in science. School superintendents (CSSE 18:85) and parents think any trend away from science education should be reversed (CSSE 17:20, 18:35). There was considerable support from all groups for a federal role in improvement of science education (CSSE 18:100) and there is some evidence that younger students at least, "wish they had more science in school" (57% yes, 34% no) (NAEP, C01 E05-B). Most states require at least one year of science (RTI 25).

Although there seem to be general positive attitudes about the value of science education, there do not appear to be strong forces working to promote science education (CSSE 19:10). School superintendents do not appear to give science high priority (CSSE 17:20); state science requirements are declining (OSU 121), and there is some evidence that science education is being displaced by emphasis on areas such as the "back-to-basics" movement (CSSE 5:28, 17:19, 18:55), and vocational education. It appears many people regard the basics as being the 3-R's and assume they can be learned separately and then applied without difficulty to any field of thought. Although teachers generally express positive attitudes about the value of science, "A substantial number of teachers do not enjoy teaching science, do not enjoy science themselves, do not take science-related coursework after they graduate, and do not study science on their own" (OSU 122). In what may (or may not) have been an extreme case, one elementary principal said, "I've had to almost force someone to put the science kit in their classes. No one wanted to have anything to do with it" (CSSE 10:19).

### Views of the Nature of Science

Beliefs of teachers and other adults about the nature of science is one important determinant of the kind of science education that occurs in classrooms. "The teachers' philosophy regarding what and how science should be taught has a strong influence on how teachers teach " (OSU 20). One teacher seemed to be reflecting the apparent majority opinion when she said, "The kids are going to dig out the facts. That's what science is, finding out the facts " (CSSE 1:27). If this statement is taken literally, all three facets of inquiry are ignored; in reality, facts become facts with theory and are verified as facts through inquiry processes.

### Resources Available

Because of its dependence on innovative curriculum development, non-textual materials, inservice education, building space and other material and human resources, inquiry education is especially sensitive to the level of support it receives. In many locations, real money available for science and science materials has been declining as more budget pressure is being exerted by other needs, such as career education and special education (OSU 122; CSSE B:4, 19:25/26, 18:41, 6:23). About half the superintendents and science supervisors felt budget cuts had seriously affected the science curricula, but fewer than 20 percent felt that such cuts had resulted in "more teaching from textbook, less with project and lab work " (CSSE 18:41).

A number of curricular developments in the last fifteen years have resulted in inquiry-oriented materials (OSU 21). At the secondary level, however, they were still subject-matter oriented and allowed little room for the spontaneity necessary for inquiry (OSU 180-1). State and federal support of the new developments (which tend to be inquiry-oriented) peaked in the Sixties but dropped considerably since (OSU 133). At one point in the 1960's, more than 30 million dollars were earmarked by NSF for curriculum development. The level of support was less than 8 million dollars in 1975. The materials were largely in text form, and teachers have made little use of the rich supply of supplementary materials available for teaching science as inquiry; they have preferred to use the texts as defining the course.

### The Valuing of "Inquiry"

Information regarding the perceived importance of inquiry-related learning appears ambiguous. Inquiry-related goal statements exist at the local and state levels (OSU 160). Teachers and principals rank "information-processing and decision-making skills" very important (OSU 85, 179), and generally value first-

hand learning (CSSE 1:25, 10:12). However, at the state level, inquiry-related goal statements appeared in only 8 or 42 states responding; whereas, 18 states listed content-oriented goal statements (OSU 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 to teach facts (CSSE 1:42, 12:5, 13:17, 19:5), "things which show up on tests" (CSSE 13:18), "basics" (OSU 30, CSSE 9:3), and to stress structure and the work ethic (CSSE 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 (RTI 39), and only 55 percent of the states had as many as one person working three-fourths time as a science supervisor (RTI 32).

#### The Teacher as Decision-Maker

Classroom teachers appear to be the ultimate mediators of all the contextual forces described above. "Teacher autonomy with regard to what is taught and how it is taught appeared widespread and should not be discredited" (CSSE 13:3). "Almost every science teacher had strong ideas as to how the 'basics' in science should be defined and as to what kinds of inquiry were good for students - and these ideas were continuing to be the prime determinant of what went on in that teacher's classroom" (CSSE 12:5).

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 slightly above teachers as sources of information (RTI 152; Table 73).

#### Teacher Skills Related to Inquiry

The teaching of inquiry requires a number of teacher skills which are not commonly required in traditional education. Many teachers are ill-prepared, in their own eyes and the eyes of others, to guide students in inquiry learning (CSSE 4:10, 12:4, 13:5; OSU 82-83; RTI 47, 142, 148), and over one third feel

they receive inadequate support for such teaching (RTI B:106). Most teachers had not had adequate training that would make them respond "instinctively" to the fruitful observations of a student or the penetrating questions of a thoughtful student (CSSE 16:8). Their college science training was not likely to emphasize process skills (OSU 53) or research experience (CSSE 12:7). There have been some attempts to improve process skill development in teacher training programs (OSU 57), and about half of the practicing teachers in 1970 had attended NSF workshops (OSU 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 (OSU 79) and that participation in designing inquiry lessons is more important than the knowledge of science in the development of process teaching skills (OSU 66). However, the newer curricula (with their inquiry focus) had little effect on teacher certification standards (OSU 52).

The educational background of school principals does not generally prepare them to supervise the teaching of science (RTI 46). Only about 10 percent of the principals were science majors (compared to 28 percent social studies majors and 20 percent English majors).

#### Teacher Opinion About Inquiry Teaching

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

The second major reservation teachers expressed about inquiry teaching was that it didn't work for most students (CSSE 18:68). They see it as causing confusion (CSSE 1:64) and too difficult for any but the very brightest student (CSSE 1:29, 1:92, 12:7). Some teachers, however, see the necessity for providing concrete, hands-on experiences to lower ability students (CSSE 12:42). Apparently, inquiry experiences are considered abstract and difficult by some teachers, but concrete and simple by other teachers. This situation adds more evidence to support our growing realization that the words "inquiry" and "process" have widely diverse, often conflicting, meanings for many teachers and for many science educators.

### The "Preparation" Ethic and Inquiry Learning

There is considerable evidence that many teachers and parents consider the primary purpose of science education to be preparation for the next level of schooling (CSSE 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 (CSSE 4:8), the content of college courses (CSSE 13:1) and the intention of most students (70%) to go on to college (CSSE 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 certainly 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 goal of instruction. Although there is some evidence that there is a trend toward thinking of school classes as tools for eventual careers in a variety of fields rather than as a prelude to becoming a "scientist" (CSSE 12:23), this new intent of preparation is still not an indication of any shift toward greater emphasis on inquiry.

### The "Socialization" Goal and Inquiry Learning

There is considerable evidence that "socialization" of students greatly affects classroom activities. The CSSE Study was replete with evidence that the "socialization goal" often outweighed science-related goals in determining the nature of classroom activities (CSSE 16). The socialization goal is manifested in activities stressing authority and discipline; and for many teachers, inquiry teaching is not conducive to these emphases.

Classroom activities which appear to many teachers to enhance socialization include written homework assignments, classroom recitation and preparation for tests. Unstructured, open-ended activities without a "single correct answer" appeared to detract from teacher pursuit of the socialization goals.

### Transactions (Program Implementation)

In this document, program implementation is defined as the set of activities exposing students to opportunities to learn about scientific inquiry. These activities include investigation of natural objects and events with the goal of formulating testable explanations of these phenomena. It includes student formulation and communication of ideas to other students and to teachers. It also includes the design and conduct of a variety of investigations in which the tools, equipment, and instruments of science are used to extend the senses, render data more precise, and to produce data not otherwise obtainable. The data sources (RTI Report, Case Studies, ERIC Review, NAEP data) were examined to identify those activities that might have some influence, either positive or negative, on inquiry-related student outcomes.

At the gross level of counting, 43 of 124 pieces of information describing various transactions were judged as being facilitators of learning science as inquiry. Twelve were neutral or unknown, and 69 were seen as describing transactions that would seem to be barriers to effective learning of scientific inquiry or process skills. While this count in no way represents equivalent instances, it does seem to generally describe the current status.

#### Facilitative (Positive) Transactions

The data sources describe the existence of several transactions in the classroom that would appear to work toward the development of scientific inquiry skills among the nation's youth. These include science being taught by trained and sympathetic teachers, use of inquiry-oriented curriculum materials, student exposure to science, availability and use of science laboratories, manageable class size in science, and an emphasis on science processes in recent years. And, while judgments as to the adequacy of these transactions is momentarily delayed, it does seem important to document their existence.

The RTI Study (RTI 10) pointed out that teachers who had been to NSF institutes were more likely (73%) to use manipulative materials in their classroom. They also are more likely to use the NSF-supported materials, since many of these institutes (80% in 1974) are designed to implement the new curricula. In 1977, 12%, 32%, and 47% of the science teachers in grades 4 - 6, 7 - 9, 10 - 12 respectively, had

attended at least one NSF institute (RTI 69). These teachers were likely to be providing some science experiences that would facilitate inquiry development in children. (It must be noted that whether or not this is in fact occurring will be determined from an examination of the student outcomes.)

Some science teachers expressed sympathy toward the value of inquiry and did tell students about the tentative nature of science, how scientists work, and how problems are solved. Several instances of inquiry-based lessons were observed by the CSSE field workers. As Stake points out (CSSE 12-26), "No end has come to the teaching of the values of science as a contribution to thinking, problem-solving, and preparation for the tasks of life. But, it was a relatively quiet evangelism in the CSSE schools."

New NSF materials with their claimed inquiry orientation have found their way into many science classrooms. Using these materials should enhance the likelihood of learning about scientific inquiry (OSU 19). Thirty percent of the elementary schools are using one or more of the NSF-supported science curricula (OSU 16). The figure increases to 60 percent among the secondary schools (RTI 80).

At the elementary level, science is usually taught in self-contained classrooms by the elementary teacher. In grades K - 3, about 95 minutes per week are devoted to science. In grades 4 - 6, the average is 175 minutes per week (RTI 58).

Science courses are offered in all the schools of the nation and all states require at least one year of science at the secondary level; some require two years with one being a laboratory-based science course. In 1977, nearly 50 percent of the students in grades 9 - 12 were enrolled in science (RTI 58; NCES). In these classes the average amount of time spent on science is about 250 minutes per week.

Opportunities to learn science are also occurring outside the science classroom. Forty-eight percent of the teachers reported supervising science clubs or fairs (CSSE 18:22) and a majority of the nation's teenagers have done science projects and worked with science related hobbies (e.g., 68% and 46% of the thirteen year olds) (NAEP C01X01).

Approximately 50 percent of the NAEP thirteen-year-old sample (C04A07) reported they solve scientific problems outside science classes using scientific methods. (Often - 13%, sometimes - 41%, seldom - 34%, never - 12%). In addition, many students reported their science teacher encouraged them to "think for themselves", 67%; "ask questions", 35%; "state opinions", 57%; and "give own ideas", 66% (NAEP, C01T03), C01T01). About half of the students said science classes

made them feel curious, with another third reporting this occurred sometimes (CO1E04).

Science laboratories exist and are used in most of the nation's schools. Fifty-nine percent of the teachers in the RTI Survey reported their students had used manipulatives during the most recent science class (RTI 106). The Case Study writers mentioned widespread use of "hands-on" laboratory experiences and the availability of facilities and equipment. The single most-often mentioned inquiry-related activity among our data sources was that teachers believed in and used the science laboratory for hands-on experiences. Fourteen of the 124 items pertaining to inquiry transactions addressed this trait.

Class size in science averaged about 25, which should make inquiry possible and/or manageable. Contrary to common lore, counselors were reported as not discouraging students from enrolling in science (CSSE 18:87). In addition, the Ohio State literature review suggests there has been an increased emphasis placed on the processes of science in many new programs (OSU 19). Finally, several instances of effective inquiry classrooms and teachers were reported in the Case Studies (e.g., CSSE 9:6; 4:10; B:16; 3:103; 5:4; 9:7; and 3:101). For example, one observer reported . . . "(the teacher) does not use the text as an instrument of propaganda, for students are able to challenge answers; and the fact that the teacher often refrains from giving clear indications of correct answers means that this is a lesson where students are encouraged to think and reason for themselves" (CSSE 6:30).

#### Resistive (Negative) Transaction

Unfortunately, for those who value inquiry, the picture presented in the preceding section has another side. An number of transactions were found in the data sources that would seem to be working against the development of learning through inquiry. The major factors that emerge are listed below and then explained in greater detail.

1. Not much time is spent on inquiring.
2. Little science is taught at the elementary level.
3. There are many pressures on teachers which compete for time to learn inquiry.
4. Even when hands-on experiences are provided to children, they are not characterized by problem solving.
5. Student disruption and its control work against inquiry development.

6. Teachers have not had many inquiry-type experiences themselves and appear to misunderstand it.
7. Inquiry learning is a difficult and high-cost operation.

The following quotes were taken from the CSSE Report and portray the general situation in the eleven sites selected for study:

"Teaching science-as-inquiry through discovery, or learning science by doing what scientists do, was not widely practiced in the classrooms I observed" (CSSE 9:6).

"Seldom was science taught as scientific inquiry - all three subjects were presented as what experts had found to be true."

"From our survey we estimate the median to be about 10% time spent in inquiry teaching, still a lot higher than our field observers reported." (CSSE 16:31).

These and other data on classroom practice gleaned from the data sources suggest little inquiry experience in science classes.

At the elementary level, the problem is compounded by the lack of exposure, particularly as the return-to-basics movement grows. Many teachers do not have time (they believe) during the day to devote to science. In one large district, a field observer reported, the last hour of each day (1:30 - 2:30) was used to accommodate art, music, health, P.E., and science (CSSE 5:9).

The RTI Study reports an average of 95 minutes per week at grades K-3 and 175 minutes in grades 4-6. But, time reported by teachers and time observed by the field observers are two different things. Stake concludes, "at the elementary level many teachers cannot teach science and many do not try" (CSSE 12:61).

There are many pressures competing for time (basics, integration, mainstreaming, socialization, etc.) and teachers are not strong enough in their commitment to inquiry learning to resist its erosion. The immediate problems of the day were too demanding, too challenging to permit the attention and changed teaching role that inquiry classes require.

Although science laboratories and equipment are wide-spread and many students performed experiments, the work was still guided by the textbook and the materials. Instruction tended toward the formal and the didactic (CSSE 2:6). Science was taught as a rhetoric of conclusions rather than as a process of discovery (CSSE 19:3). Even in the lab, the students were trained to seek the right answers (CSSE 13:59). The doing of the assigned text problems dominates over the doing of science (CSSE 5:5). The text becomes the instrument of teaching and learning (CSSE 19:8).

The primary actors in the daily classroom drama, student and teachers, often exhibit characteristics that tend to diminish inquiry learning. Students lack the commitment to learn and teachers do not set very effective role models for inquiring behavior. Several field observers noted sufficient student problems to interfere with learning (CSSE 9:17, 2:10), and 19 percent of a national student sample indicated student immaturity as a reason for dissatisfaction in science classes.

The way teachers handled their classes suggests a lack of understanding of the elements of true inquiry. Teachers tended to tell students about it rather than have them become involved in seeking solutions to problems. "Science was something teachers 'took' in college, but it was not something they experienced as a process of inquiry. It was not surprising then to find creative inquiry was not what we found in those eleven high school laboratories - except in rare circumstances " (CSSE 12:7).

Teaching science as inquiry is a demanding pedagogical task. Unlike a "science is facts" approach, it requires an understanding of the nature of scientific knowledge, of the developmental characteristics of learners, of a variety of pedagogical skills, and a capability of thinking as one is teaching. It requires a considerable expenditure of time and effort, and its perceived value appears minimal to most teachers. The Case Study report illustrates this point very well:

"The teachers in those schools testified that it (inquiry) was very difficult, the results come so slowly, they never seemed to know just the right questions to raise. They stated they had to prepare so much more for inquiry lessons than for regular teaching that only a small percentage of time could be spent on inquiry teaching " (CSSE 12:6).

The perceived difficulty of such activity tends to diminish its appearance in science classrooms and probably explains the few instances noted in the data.

### Evaluation

Evaluation of student progress and of science programs was considered to be a transaction. That is, it was something that did or did not occur that may have an effect on learning inquiry skills. Only a few references to evaluation were found by the inquiry group and all tended to suggest the evaluation activity was prohibitive of inquiry teaching.

The evaluation which is occurring tends to ignore the process goals of science. The testing movement concentrates, instead, on those easily measured

outcomes: facts and knowledge (OSU 153). Teacher-made tests, competency-based programs, and national accountability movements, thus far, have not given much attention to the process outcomes of instruction. The third cycle of NAEP testing represents a marked departure over previous tests and may be an important catalyst for improving evaluation efforts in the inquiry domain.

Student Outcomes

Evidence of the extent to which students currently are achieving the desired outcomes with respect to Inquiry comes primarily from the NAEP data and from some of the CSSE reports. In many instances the evidence is fragmentary, and we necessarily have had to make certain inferences on the basis of only a few NAEP exercises or CSSE site observations that we believe to be representative. This process is fraught with pitfalls, to be sure, and we are well aware that many exceptions probably exist somewhere in the U.S. regarding every general statement we make below. In keeping with the safeguards and customs of inquiry, we offer the following statements as hypotheses, partially supported, about the current status of Inquiry student outcomes.

The status report organizes the domain of inquiry under the same three subdivisions as in the desired state report.

Observing and Measuring

Elementary school children appear to acquire skill in making simple observations of objects and phenomena. On NAEP paper-and-pencil exercises (e.g., NAEP 204064, 204083, and C56C04) which assess aspects of this skill, between 82 percent and 88 percent of nine-year-olds generally choose the correct alternative. There are no data on junior high and high school students' skill in making observations. With regard to the related skill of describing observations they have made in appropriate language, elementary school students appear to perform quite creditably when the object or phenomenon to be described is relatively simple, but they do not perform so well when the phenomenon is complex. For instance, when observing objects through a tube fitted with a convex lens (NAEP C56C05), between 90 percent and 96 percent of the nine-year-olds correctly described the appearance of the objects as smaller, farther away, and right side up. Similarly, 90 percent of the nine-year-olds gave an acceptable verbal description of their observation of a photocell (NAEP 204001). On the other hand, only 22 percent of the nine-year-olds gave an acceptable verbal description of their observation of the turning gear wheels of a hand-operated eggbeater (NAEP 204007). On this same exercise, 37 percent of thirteen-year-olds gave an acceptable verbal response, showing some increase with increasing age. We have no data concerning high school students' skill in describing observations in appropriate language, but students presumably continue to improve in this skill after age 13 as their

verbal proficiency matures.

When students are tested for aspects of measuring skills by means of paper-and-pencil exercises, they generally perform better than when their measuring skills are assessed by means of manipulative exercises. For example, 93 percent of the nine-year-olds correctly read the scale on a drawing of a thermometer in a NAEP paper-and-pencil exercise (NAEP C54C13). Similarly, when shown a drawing of a rock being immersed in water in a graduated beaker, 58 percent of the nine-year-olds chose the correct value for the volume of the rock (NAEP 202081). In another NAEP paper-and-pencil exercise (NAEP C54C09), a drawing of the face of a pressure gauge is displayed, and this gauge was read correctly by 57 percent of the thirteen-year-olds and 75 percent of the seventeen-year-olds. By contrast, when students were given a manipulative exercise (NAEP 204004) on measuring temperature, only 72 percent of the nine-year-olds said that they knew how to read a laboratory thermometer (in contrast with 93 percent who correctly read a thermometer in a drawing). Among the thirteen-year-olds, 82 percent said that they knew how to read the thermometer, and so did 88 percent of the seventeen-year-olds. When required to measure the volume of water in a graduated cylinder (NAEP 204046), only 18 percent to 19 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. The finding here is consistent with the data in NAEP exercise C09U01 where 32 percent of the thirteen-year-olds reported that they had ever used a graduated cylinder and 64 percent of the seventeen-year-olds said so. Nonetheless, this is not a particularly strong showing for the high school seniors on a rather rudimentary measuring skill.

Regarding the practice of averaging a set of measurements to obtain the best value (NAEP C54C04, C54C07), approximately half of the thirteen-year-olds appear to be acquainted with the practice and so are between 60 percent and 70 percent of the seventeen-year-olds. Only 29 percent of the seventeen-year-olds know about the additional trick of dropping an obvious outlier from the set of observations before averaging (NAEP C58C16). When asked to make an estimate of the length of a 10-cm line or drawing of a pencil in a multiple-choice exercise (NAEP C54C01, C54C08, C54C12), 38 percent of the nine-year-olds, approximately 55 percent of the thirteen-year-olds, and approximately 60 percent of the seventeen-year-olds do so successfully. Estimation of the length of a 7-cm line in a fill-in exercise (NAEP 204061) was accomplished successfully by 18 percent of the nine-year-olds, 21 percent of the thirteen-year-olds, and 21 percent of the

seventeen-year-olds. Overall, it is clear that many students at every age level are not too accurate in estimating length in metric units.

Appropos of measuring skills in relation to Goal Cluster I (Personal Needs), NAEP exercise no. C09D08 resulted in these data:

	<u>Age 9</u>	<u>Age 13</u>	<u>Age 17</u>
Percentage of students who report having taken their own temperature	38	70	85
Percentage of students who report having taken their own pulse	28	67	83

This reflects a salutary increase in exposure to the particular measuring skills with increasing age. There is no evidence here, however, about how well students at each age can measure their body temperature or pulse. Data from other exercises suggest that the percentages for skilled performance would be much lower than the percentages for exposure which are shown here.

This last point is worth pondering in relation to the student outcomes for the entire range of Observing and Measuring skills. It appears that students have indeed been exposed (either in science classes or in school or elsewhere) to many of these skills. However, when skilled performance or somewhat sophisticated application of Observing and Measuring skills is assessed, relatively few students are generally successful.

#### Seeing a Problem and Seeking Solutions

This section of student outcomes related to the processes of scientific inquiry goes beyond the skill behaviors of the previous section to the intellectual processes associated with inquiry in science. We have no data in our sources concerning the students' ability to recognize a problem (which is where scientific inquiry usually begins), but we do have some data as to how well students of different ages can formulate working hypotheses, select suitable tests of hypotheses, and design appropriate procedures for performing experimental tests.

In NAEP exercises (e.g., NAEP 204001, 204004) where students have observed a particular physical phenomenon and are asked to formulate a working hypothesis concerning it, only a small minority of students at each age level come up with acceptable hypotheses. Approximately 5 percent to 7 percent of nine-year-olds, approximately 17 percent to 21 percent of thirteen-year-olds, and approximately 26 percent to 36 percent of seventeen-year-olds do this intellectual

task successfully. In another NAEP exercise (NAEP 204107), seventeen-year-olds were asked to suggest four working hypotheses for the observed differences in yield of two fields of corn. One acceptable hypothesis was suggested by 79 percent of the high school seniors, two by 75 percent, three by 69 percent, and four by 60 percent. The evidence from these several NAEP exercises suggests that only a small minority of nine and thirteen-year-olds can formulate acceptable working hypotheses. For seventeen-year-olds, success in formulating hypotheses seems to depend to a large degree on their familiarity with the phenomena they are asked to hypothesize about. About three-fourths of the seventeen-year-olds, formulate acceptable hypotheses concerning a rather familiar phenomenon, whereas only about one-third do so in the case of a less familiar phenomenon.

Several exercises (e.g., NAEP 204070, 204090, 204137, C57C03) presented a certain hypothesis concerning some biological or physical event and asked the student to select or specify an appropriate test of the hypothesis. This type of exercise was used with students at all three age levels, though those exercises which were designed solely for the seventeen-year-olds (e.g., 204104, C58C14) generally were more wordy and complex. The findings are that, on the average, approximately 64 percent of the nine-year-olds correctly select appropriate tests of hypotheses (the range for four exercises is from 48 percent to 76 percent); and, approximately 75 percent of the thirteen-year-olds also do this successfully on the average (the range for five exercises is from 63 percent to 82 percent). For the seventeen-year-olds doing generally more complex exercises than the younger students, the mean percentage who correctly select appropriate tests of hypotheses is 73 percent, with a range for six exercises from 56 percent to 89 percent. Based on our understanding of children's intellectual development, we would expect all nine-year-olds to be successful in performing the mental operations associated with selecting an appropriate test of an hypothesis, and this is indeed borne out by the finding that approximately one-third (on the average) of the children in this age group do not succeed on exercises which require such intellectual processing. Although thirteen-year-olds are developmentally more capable of doing this intellectual processing, we still find that approximately one-fourth (on the average) of the students in this age group do not perform successfully on exercises in which they are asked to select appropriate tests of hypotheses. Exactly the same remark applies to the

seventeen-year-olds.

The ability of students to design procedures for performing experiments or experimental tests was assessed in a sizable sample of NAEP exercises. At least 17 different exercises assessed aspects of this behavior in various science assessment years, and students at all three age levels had several opportunities to demonstrate their proficiency on this type of exercise. The exercises covered a goodly number of different experimental situations and procedures, ranging from a procedure for finding the poles of an irregularly shaped magnet (NAEP 201048), to a procedure for removing salt from salt water (NAEP 204073), to determine how much a person grows in one year (NAEP 204090), to an experimental procedure for testing the effect of sugar on mice's teeth (NAEP C57C01), and many more. The findings for these exercises can be summarized as follows:

AGE GROUP	NUMBER OF EXERCISES	RANGE OF PERCENTAGES OF CORRECT RESPONSES	MEAN OF PERCENTAGES OF CORRECT RESPONSES
9	7	37% to 82%	59%
13	12	14% to 88%	61%
17	8	21% to 81%	65%

The most impressive feature of these findings is the very large ranges of the percentages of correct responses to the several exercises for each of the age groups. The explanation for this result is that the students' success in responding correctly to these exercises depends to a large extent on how much they know about the particular experimental procedures that are called for in the exercises. In other words, the knowledge component looms large in these exercises, and the process component is correspondingly small. Although the data show that, on the average, approximately 60 percent of the students at each age level respond correctly to exercises which call for the design of procedures for performing experimental tests; this truncation of the findings is misleading. It is more accurate to say that a very high percentage of students (sometimes more than 80 percent) at each age level can correctly design procedures for performing certain experimental tests, but far fewer students (sometimes less than 25 percent) can do this for some other experimental tests. In addition, we can safely say that sizable percentages of students did not possess sufficient information about certain specific experimental procedures which the designers of the NAEP exercises considered important enough to sample at each of the three age levels.

### Interpreting Data and Formulating Generalizations

As an integral part of inquiry in science, experimental data are collected and observations are recorded. These data and observations must then be analyzed and interpreted by the investigator. From the interpretations of the data and observations, the investigator then may formulate appropriate generalizations that are warranted by the available evidence. The student behaviors included in the present section of the Processes of Scientific Inquiry include data analysis, data interpretation, and formulation of generalizations. Unfortunately, only one NAEP exercise (NAEP C58C19) sought to assess even a portion of the behavior of formulating a warranted generalization, so that little can be said about students' status on this particular inquiry process. However, a sizable sample of NAEP exercises assessed various aspects of student behaviors related to the interpretation and analysis of data. The main findings from these exercises are summarized here.

More than a dozen NAEP exercises presented experimental or observational data either in a table or a graph and asked the student to select descriptions of correct interpretations of the given data. Some of these exercises presented the data in a very simple bar or line graph (e.g., NAEP 204076, 204079, 204082, 204098, C58C12), and these exercises were used, with one exception, only in the assessment of the nine-year-olds. These young students performed remarkably well on this set of exercises. Between 85 percent and 92 percent of the nine-year-old students selected correct interpretations of the data in the simple graphs, and the mean percentage correct for four exercises was 89 percent. Other NAEP exercises (e.g., nos. 204128, C31C01, C54C03, C58C03, C58C09) presented data in more realistic tables and graphs -- more realistic in the sense that the presentation resembled what might be found in the notebook of a student who had recorded observations in an actual investigation. The findings for these exercises were:

<u>AGE GROUP</u>	<u>NUMBER OF EXERCISES</u>	<u>RANGE OF PERCENTAGES OF CORRECT INTERPRETATIONS</u>	<u>MEAN OF PERCENTAGES OF CORRECT INTERPRETATIONS</u>
9	6	45% to 63%	54%
13	6	51% to 76%	59%
17	4	59% to 82%	71%

These findings are quite straightforward. Proficiency in this type of exercise calling for interpretations of experimental or observational data is shown, on the average, by approximately half of the nine-year-olds, two-thirds of the thirteen-year-olds, and three-fourths of the seventeen-year-olds. The performance of the nine-year-olds probably can be accounted for, in part, by the psychological insight that the cognitive structures of many children of this age are not yet sufficiently developed to enable them to perform the mental operations required to interpret presented data for situations which are only described verbally, rather than being experienced concretely. This reservation does not apply to the seventeen-year-olds, however. The above findings suggest that as many as one-fourth of the seventeen-year-old students may not have attained proficiency in the scientific inquiry process of interpreting tabular or graphically presented observational data.

Several additional NAEP exercises assessed some interesting aspects of students' proficiency in analyzing data. In exercise nos. 204081, 204088, C53C01 and C58C01B, students were given a set of data and were asked to select a graph which correctly represents these data. Two exercises sampled this behavior at each age level, and the mean percentage of correct responses was 38 percent for the nine-year-olds, 35 percent for the thirteen-year-olds and 60 percent of the seventeen-year-olds. Five other NAEP exercises (nos. C48C01, C58C01A, C58C06, C58C07, C58C10) assessed the students' proficiency in interpolating between or extrapolating beyond observed data points presented in either a table or a graph. Three exercises sampled this behavior at each of the two upper age levels, and the percentage of students who performed this type of data analysis correctly ranged from 56 percent to 77 percent for the thirteen-year-olds (mean = 65%) and from 30 percent to 80 percent for the seventeen-year-olds, on somewhat more difficult items, (mean = 63%). The indications from the two groups of assessment exercises just reviewed are that at each age level the types of data analysis behavior assessed have been mastered by fair proportions of students, but ample scope remains for improvements in students' proficiency in the scientific inquiry process of data analysis.

#### Building, Testing and Revising a Theoretical Model

Although all available NAEP exercises were carefully studied, we were unable to find any exercise which sought to assess the processes associated with theory

building and theory testing. Moreover, none of the CSSE reported any observations of science students engaged in these processes. Lacking any evidence, we must perforce remain silent regarding the status of students' proficiency in building, testing, and revising theoretical models. Speculations regarding the status of this particular student outcome might be offered, but this is not an appropriate place for such an indulgence.

#### Scientific Knowledge as a Product of Scientific Inquiry

"In most schools, passing on a lore studied by the present adult generation was a prime responsibility" in spite of "revolutionary developments in modern science and technology" (CSSE 13:7). Excellent teachers know that science is tentative and that evidence is the basis for knowing, but this is put aside in order to accomplish daily tasks such as teaching facts and the right answers (CSSE 12:9). Science is taught as a rhetoric of conclusions (CSSE 19:8).

The nature of science is a crucial issue for science education because a teacher's conceptualization of it determines in large measure what is taught in the classroom (CSSE 11:7). The general public would not seem to have a sophisticated grasp of the nature of science, as evidenced by their behavior in textbook controversies (OSU 117).

Students' achievement was generally high (65% and better) in their understanding the importance of, and the nature of, scientific observations (C08A01, 204095, C58C15) and the importance of theories to science (C08A02). Almost all students recognized that different scientists may give different explanations about the same observation (C08A03). Students held a fairly realistic notion that scientific inquiry is inappropriate for some aspects of personal decision-making, e.g., choosing a friend (C01U02). They expressed a supportive attitude toward the value of procedures of science outside the lab (C04A05). While students understood that one aim of science was to improve explanations about natural events (C08A02), or to seek relationships in measurements (205021), students tended to confuse the aims of science with the aims of technology (205010, 205019). Moreover, they expressed the view that scientific knowledge represented all there was to ever know about typical science topics (105010, 105011). The nature of scientific models was generally misunderstood (204102, C41C01, C41C02, C41C03). The source of scientific laws was poorly understood, (105009) and students found it difficult to pick from a list of statements an example of an hypothesis (204103). Only about one half of the students realized what some basic assumptions underlying scientific inquiry were, e.g., susceptibility

of nature to logical explanations (C04A01), and orderly classification (105003), causality (C08A01), consistency in observation (C54C02, C54C03). Less than half of the students did not realize there are errors in measuring car speed and in measuring the length of a truck (C54C05). Even fewer appreciated that there are errors in measuring "time" when a computer is used (C54C05).

### The Diversity of Tactics and Strategies in Scientific Inquiry

The five to eight steps of "the scientific method" have been used in the school curriculum for a long time -- 50 years at least. In spite of the fact that their role in the disciplines from which they came has waned considerably, teachers and texts appear to propagate the myth (CSSE 13:7). (Recitation of children in one class: "define the problem, collect information, make an hypothesis, experiment, organize observations, record observation tables and graphs, draw conclusions, prepare a report" (CSSE 4:15):

However, most students expressed the view that scientists may use many different methods to solve a single scientific problem (C08A01). (There is no evidence in NAEP concerning students' beliefs in "the scientific method" as a way of developing either answers to their questions (C08A01), or solutions to all problems (205022). They are also conscious of the scientific strategy of reading up on an area before embarking on a new study (C53C04, 105013). The importance of unexpected observations to the process of scientific inquiry is generally appreciated (C08A01). The awareness of some scientific strategies (e.g., to observe natural behavior of animals in a natural rather than in an artificial setting) developed in the minds of youngsters all the way from not being understood by nine-year-olds to being well understood by seventeen-year-olds (C56C02). Many students properly believed that a typical scientific activity did NOT include selling tickets (205016). However, very few students knew that a scientist would NOT list conclusions to be proved as an initial tactic for working on a science problem (205023).

### The Self-Testing and Empirical Aspects of Scientific Inquiry

The importance of independent verification is not widely appreciated among students (C53003), nor is the importance of controlling all variables in an experiment (C57C02). However, most students recognize that experimenting is a usual activity for scientists (105015) and requires similar skills and knowledge in all fields of science (C71C10). Only older students realize that opinion statements are not amenable to scientific investigation (205018). Most students

recognize that scientists publish experimental results: to share findings, to allow for independent verification and to add to scientific knowledge (C53C05).

About 65 percent of thirteen-year-olds and about 75 percent of seventeen-year-olds understand that theories: will change (C08A02) in light of new observations (C51C01), are useful even though incomplete (C08A02), and are important in predicting events (C08A02). However, only 10 percent expressed the view that simplicity was a criterion for choosing between equally useful theories (C58C17). When responding to items which dealt with old theories, students indicated that old theories: had contributed to today's knowledge, had guided experiments, the results of which led to present understandings, and had been suggested by scientists who could not have known better (C51C01). Many students recognized that scientific models are used for prediction (C51C04).

### Strategies of Inquiry

Generally, rational and empirical inquiry is consciously absent from most schools (CSSE 1:74; 3:46; 12:9; 15:6).

#### Inquiry Related to Values.

In many communities a sizable and potentially vocal minority takes a stand against inquiry into controversial issues (RTI 77; CSSE 12:30). Teachers' behavior in avoiding such inquiry, irrespective of the teacher's own values, reflects this state of affairs (CSSE 12:28). Alternative schools seem able to inquire into values (CSSE 3:102).

#### Inquiry Related to Scientific Knowledge.

Approximately 50 percent of students engage in scientific inquiry outside of science classes, and it is more frequent for thirteen-year-olds to do so than for seventeen-year-olds (C04A07, C04A04). A larger proportion of students would seem to have engaged in scientific inquiry at one time or another. This is a function of age: 50 percent for nine-year-olds, 65 percent for thirteen-year-olds, and 75 percent for seventeen-year-olds (C09D08). Many more would like to (C09D03).

Nine-year-olds expressed a negative feeling towards finding answers to questions on their own, but the same group expressed positive feelings toward making discoveries for themselves and toward thinking of different ways to solve problems (C04A08). When given the opportunity to recognize the appropriateness of scientific inquiry to solve a problem, 57 percent of them properly recognized how to proceed, while 32 percent "incorrectly" appealed to the authority of the teacher (C52C04).

### Inquiry Related to Problem-Solving and Decision-Making.

A large proportion of thirteen and seventeen-year-olds said they often engaged in problem-solving strategies outside of science classes (C04A04).

A number of NAEP items were concerned with problem-solving and decision-making for science-related social problems or issues. For most of these items, the seventeen-year-olds did much better than the thirteen-year-olds.

Most students were able to recognize a main issue in a science-related social problem (C91C01). Many fewer knew that one of the first steps in making a good decision involves deciding what the goals are (C91C04). Students usually did well at distinguishing between goals and obstacles (C91C13) and at defining a problem in a decision-making situation (C91C05). Students appeared to be competent at knowing what strategies would be helpful in collecting evidence for decision-making (C91C08), though they were somewhat less sophisticated in knowing whether or not to make a decision or to collect further relevant information (C91C15). Only half said they themselves gather a variety of information before making a decision (C04A01). Almost all students recognized evidence as being relevant or not to a particular decision (C91C09). About 60 percent to 70 percent of the teenagers knew that a person should evaluate the consequences of decisions, though few nine-year-olds knew this (C91C02, C91C06, C91C10, 205015). However, when faced with a situation in which they actually had to choose to do this, only about half did so (C81C06).

### Safeguards and Customs of Inquiry.

A science teacher expressed the belief that scientific inquiry values may be transferred to a social context, e.g., a value such as accepting different view points (CSSE 4:8). This rationalized her desire to teach the safeguards and customs of inquiry. However, most teachers attended to values which would reinforce the teachers' relationships with their students. Consequently, values supporting the careful, productive, conforming, trustworthy subordinate were emphasized, while other values associated with speculative critical thinking were ignored or even ridiculed (CSSE 12:27). However, this is not to say that students are not exposed at one time or another to the "grand thinker" role model (observing, skeptical, relativistic, speculative, searching for flaws in thinking) or to the "lab tech" role model (precise, objective, analytic, impersonal and looking for the definitive experiment) (CSSE 12:26). On the other hand, in general education

classes developed for "minimal competency" and "functional literacy", the safeguards and customs of inquiry are not given a place (CSSE 12:41 and 43).

Only a minority of teenage students express a desire to carry out activities which are closely associated with the safeguards and customs of inquiry (C02A02). They generally express an unwillingness to change their ideas in the light of new facts (C04A01), even though most of them recognize that this is an attribute of the working scientist (C08A03). Only half of the students see themselves using the accuracy values in checking school work, but a few more express that they would persevere in a task in spite of problems (C04A01). Most students acknowledge the importance of looking at all sides to a question (C04A01), the importance to the scientist of accuracy and integrity in reporting results (C08A03), and the importance to the scientist of being critical of experimental results. About one half of the students believed that a scientist should be critical of the work of other scientists, and should be openminded with respect to theories (C08A03). Students were generally successful when required to exhibit various safeguards when reading an advertisement for a pain killer (C71C03).

CHAPTER 10

INQUIRY PHASE III REPORT:  
THE ROLE OF INQUIRY IN SCIENCE EDUCATION --  
ANALYSIS AND RECOMMENDATIONS\*

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## Introduction

For many years, the science education community has advocated the development of inquiry skills as an essential 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 large discrepancies were found between what is desired and what exists. (Welch, et al., 1979). 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 statements of desired student outcomes, including our own, contain sufficient shortcomings and limitations to justify a reconsideration of our expectations for inquiry learning.

In this paper, we argue that such formulations have generally ignored the diversities 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 all students should not 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 not be appropriate to expect any inquiry-related outcomes at all! Thus, every student outcome with respect to inquiry in science education should be commensurate with individual differences, personal goals, and environmental conditions.

The process that led to this conclusion and its implications are described in this paper.

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 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 processes, science/technology and society, and elementary school science.

Each topic was studied by a group of scholars. The Inquiry Group's task 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 experiences of the task 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

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 the Phase I report.

General inquiry processes and science process skills are essentially intellectual processes. 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--the ethos--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, such as observing and measuring, seeing and seeking solutions to problems, interpreting data, generalizing, building, testing, and revising theoretical models.

The second domain, the "nature of scientific inquiry" is essentially epistemological. 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 were summarized in 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 pursue transactions (to be presented in the next section) of various kinds without undue reorganization or loss of time.

Curricula include explicit statements of desired student outcomes that give attention to contexts, 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-attuned to the characteristics of the student population, including their needs and goals.

### Transactions

Instruction in progress in inquiry classrooms reflects a variety of methodologies--discussions, investigative laboratories, student-initiated inquiries, lectures, debates. Teachers serve as role models in deliberating issues, in examining values, in admitting error, and in 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 formulations of responses are listened to, clarified, and deliberated with high student-student transactions. Content and

processes are inseparable. "How do we know?" enters many deliberations. 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 continuing activities in the classroom. Techniques and instruments for summative evaluation are selected and utilized in such a way that student outcomes reflecting instruction can be 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 outcome statement includes a parenthetical word to identify its domain. This section of our report will present only a sample of the 128 student outcome statements previously developed (Welch, 1978) and included in the Phase I report.

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 here 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 1 presents examples of student outcomes consistent with the point of view developed in the first phase of this study.

TABLE 1: 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  
Career Ed. & Prep.

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.

GOAL CLUSTER I  
Personal Needs

GOAL CLUSTER II  
Societal Issues

GOAL CLUSTER III  
Fundamental Knowledge

GOAL CLUSTER IV  
Career Ed. & Prep.

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The Nature of Scientific Inquiry

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(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.

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General Inquiry Processes

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(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 lighter than water" and "whatever is lighter than water floats on it.")

(Doing). Decides what the main issues of selecting a science career are.

(Doing). Values open-mindedness in those who pursue scientific careers.

GOAL CLUSTER I  
Personal Needs

GOAL CLUSTER II  
Societal Issues

GOAL CLUSTER III  
Fundamental Knowledge

GOAL CLUSTER IV  
Career Educ. & Prep.

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General Inquiry Processes (Cont.)

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(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.

### Actual Status

To determine the actual status of science education relevant to Inquiry, we consulted four recently completed studies. Three of these were conducted from 1976-1978 under the sponsorship of the National Science Foundation (NSF). One study (hereafter referred to as OSU), carried out at Ohio State University, was a 20-year literature review related to 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 (hereafter referred to as RTI), was conducted by the Research Triangle Institute in North Carolina (Weiss, et al., 1978). Eleven in-depth Case Studies in Science Education (hereafter referred to as CSSE) were prepared by the Center for Instructional Research and Curriculum Evaluation at the University of Illinois (Stake and Easley, et al., 1978). Our fourth source for current status data (referred to as NAEP) 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 the Phase II report, a document portraying the current status of science inquiry learning in the United States (Welch, et al., 1979). 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 (CSSE 19:10), state science requirements are diminishing (OSU 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 appears ambiguous. Inquiry-related goal statements exist at the local and state levels (OSU 160). Teachers and principals rank "information-processing and decision-making skills" as very important (OSU 85,179) and generally value first-hand learning (CSSE 1:25, 10:12). However, at the state level, inquiry-related goal statements appeared in only 8 of 42 states responding, whereas, 18 states listed content-oriented goal statements (OSU 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 (CSSE 1:42, 12:5, 13:17, 19:5), "things which show up on tests" (CSSE 13:18), "basics" (OSU 30; CSSE 9:3), and structure and the work ethic (CSSE 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 (RTI 39), and only 55 percent of the states had as many as one person working three-fourths time as a science supervisor (RTI 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 (CSSE 4:10, 12:4, 13:5; OSU 82-83, RTI 47, 142) and over one-third feel they receive inadequate support for such teaching (RTI B-106). Most teachers had not had adequate training for responding instinctively to the fruitful observations or the penetrating questions of a thoughtful student (CSSE 16:8). Their college science training was not likely to emphasize process skills (OSU 53) or research experience (CSSE 12:7). There have been some attempts to improve process skill development in teacher training programs (OSU 57), and about half of the practicing teachers in 1970 had attended NSF workshops (OSU 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 (OSU 79) and that

participation in designing inquiry lessons is more important than knowledge of science in the development of process teaching skills (OSU 66).

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

The second major reservation teachers expressed about inquiry teaching was that it didn't work for most students (CSSE 18:68). They see it as causing confusion (CSSE 1:64) and too difficult for any but the very brightest student (CSSE 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 (CSSE 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 (CSSE 4:8), the content of college courses (CSSE 13:1) and the intention of most students (70%) to go on to college (CSSE 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 certainly 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 goal of instruction.

A final contextual factor is the considerable evidence that the press for "socialization" of students greatly affects classroom activities (CSSE: Chapter 16). This goal is manifested in 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 interaction 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 who are not (OSU 16).

Among teachers who have attended an NSF institute, 73 percent report using manipulative materials in their classroom (RTI 107). Twelve percent of the elementary teachers, 32 percent of the junior high teachers, grades 7-9, and 47 percent of the secondary teachers, grades 10-12, have attended at least one institute (RTI 68). Many of 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 (OSU 16, RTI 80). About 50 percent of the students in grades 9-12 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 RTI survey reported that 59 percent of the teachers involved the students with manipulative objects during their most recent science class (RTI 106). Several of the case study ethnographers observed lessons where the students were encouraged to think for themselves (CSSE 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 (Welch et al., 1979--Phase II Report). 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" (CSSE 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" (CSSE 12-7). Inquiry teaching is a difficult and time-consuming task and teachers are not prepared, 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 data for testing carried out in 1968-69, 1971-72, and 1976-77. It was in the latter testing period that a larger share of attention was directed to measuring student competencies in the process or 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 classes 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 generally successful (cf., Phase II report). For example, 82 percent of the thirteen-year-olds reported that they knew how to read a thermometer, but in measuring the volume of water in a graduated cylinder 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 in generating or selecting hypotheses dropped considerably.

The ability of students to design procedures for carrying out experimental tests comprised a large share of the NAEP data. A very high percentage of students (sometimes more than 80 percent) at each age level (9, 13, and 17 year-olds) can correctly design procedures for performing certain experimental tests. but far fewer students (sometimes less than 25 percent) can do this for other experimental tests. In addition, sizable percentages of students did not possess sufficient information about certain specific experimental procedures which the designers of the NAEP exercises considered important enough to sample at each of the three age levels. Ample room for improvement exists for students' proficiency in the process of analyzing data, in spite of cases in which certain types of data analysis have been mastered by a fair proportion of the students.

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. But 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: (a) 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 9 and 13 year-olds realized that all scientific topics are not thoroughly understood. About half of the students believe 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.

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, Dilemmas and Alternatives

A point-by-point summary comparison between the original Phase I Inquiry Report (desired state for science education) and the Phase II Inquiry Report (actual status of science education) may be found in Appendix A. By comparing the two reports, we discovered substantial discrepancies, as summarized below.

As discussed in the preceding section, the widespread, espoused support of inquiry is more simulated than real in practice. Perhaps this discrepancy may be understood by analyzing the context, including a prospective teacher's education and professional training, where inquiry goals are articulated but the practice of inquiry receives negligible attention. The greatest set of barriers to the teacher support of inquiry seems to be its perceived difficulty. There is legitimate confusion over the meaning of inquiry in the classroom. There is concern over 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 web of barriers to teaching scientific inquiry becomes even more complex with a myriad of 'vicious cycles,' nonlogical rationalizations, and social justifications. While these complications are identifiable, the important point is that a desirable context for inquiry instruction is lacking.

The transactions 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 they have on classroom practice. The following statements summarize the state of affairs related to the transaction of teaching scientific inquiry:

1. Not much time is spent on inquiring.
2. Little science is taught at the elementary level.
3. There are many pressures on teachers which compete for the time it takes to learn inquiry.
4. Even when hands-on experiences are provided to children, they are not characterized by problem solving.
5. Student disruption and classroom control work against inquiry development.
6. Teachers have not had many inquiry-type experiences themselves and appear to misunderstand it.
7. Inquiry learning is a difficult and high-cost operation.
8. Evaluation of inquiry outcomes is perceived as prohibitive compared to the more easily measured traditional outcomes.

In regard to outcomes, the CSSE data suggest: (a) that the community mitigates against inquiry into values; (b) that the teacher's use of authority in science classrooms discourages problem-solving, decision-making and scientific inquiry; and (c) that 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. A noticeable discrepancy exists between this state of affairs and the desired outcomes specified in the Phase I Report.

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 (Phase II Report, Section "Transaction") 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, and increase in "test-wisness," a sample bias due to drop-outs, an increase in reading ability, and the experiences which children gain at home and in their community.

Because of the widespread discrepancies summarized above, we have reached the unavoidable conclusion that the desired state for 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. Our expectations were far from being met in any of the three domains: contextual support, transactions, and student outcomes.

Those who value teaching 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, the education 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 far from being realized.

The time has come for the science education community to re-analyze and re-evaluate their expectations.

What are some reasonable implications of the discrepancy problem? We have 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 recognize 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 key-note 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 the 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 viable 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 Phase I Report so that our desired outcomes 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 Proposal

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 lines of evidence. 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.

#### Desired State for Inquiry Outcomes

We propose the following general framework for defining the desired state of 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 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 HAVE PSYCHOLOGICAL CONSISTENCY, BE COMPATIBLE WITH PERSONAL GOALS, AND HAVE ECOLOGICAL CONSISTENCY,

The key ideas in this general proposition deserve elaboration. By the psychological consistency of 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 via 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 constitutionally could perform the tasks.

When we say that an expected inquiry outcome should be compatible with 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 opposite 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. However, we recognize that, while the personal goals concerning adult roles are quite similar for most students, their 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 dramatics metaphor, clearly the level 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, regarding the basic process skills of scientific inquiry, the level and nature of competence expected must be conditioned by the personal goal the student has in terms of his or her adult social role and occupation. Science process skills are just one subdivision of the inquiry domain, but the same argument applies to another subdivision, general inquiry processes. However, there are probably fewer general inquiry behaviors and competencies that should be excluded on the basis of the student's anticipated social role and occupation.

We also have called for the ecological consistency of every expected inquiry outcome. 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

ecological consistency 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 copious inquiry outcomes in the first kind of school would be foolish and dishonest, but in the second instance, inquiry outcomes would have ecological consistency.

The requirements we are proposing in the general framework 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 psychological consistency would recommend more extensive expectations than have been customary regarding student outcomes in utilizing inquiry as a way of thought. The requirement that the expectations be compatible with the students' personal goals would direct prospective scientists to a heavier dosage of expected competencies in designing and analyzing experiments, and it would enjoin 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 how that should 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 pervade several curricular areas. Moreover, science education has agendas other than developing problem-solving abilities; for example, instruction in key science concepts is on the list.

### Providing Inquiry-Related Educative Experiences

The preceding section described the desired state for inquiry outcomes emphasizing that expected competencies be tailored to individual student and ecological 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 domains. 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 a longitudinally arranged inventory of those inquiry-related competencies which the individual is expected to develop throughout his or her years in school. The inventory encompasses 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, of psychological consistency, compatibility with personal goals, and ecological consistency. In essence, the goals component of the Profile is the individual's scope and sequence charts, the goals component gives direction to the student's learning program.

The programmatic component of the Profile delineates 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 lateral

slices of his or her time in school. These actions include various instructional procedures and materials which are familiar to science educators. To mention some of these, there are: (a) year-long or semester courses with defined characteristics regarding their emphasis and means of promoting inquiry; (b) self-instructional modules which develop specific inquiry-related skills or knowledge; (c) minicourses which do the same; (d) laboratory and field investigations with varying degrees of structure and varying opportunity for discovery; (e) textbooks and other reading materials with recommendations based on their varying opportunities for developing specific inquiry-related competencies; (f) 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 deploy the existing materials and techniques in effective configurations suitable to each learning situation.

In summary, we have proposed that science educators must attend seriously to the incontrovertible evidence about the uniqueness of the individual and the contextual differences in schools. We believe that this evidence is so compelling, as to warrant the construction of plans to provide educative experiences which are 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 is a large scope here for legitimate 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 not be appropriate to expect any inquiry-related outcomes at all.

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APPENDIX A

A. Point-By-Point Summary Comparison Between  
Report I and Report II

## DESIRED STATE

## ACTUAL STATUS

## Student Outcomes

Observing and Measuring

- successful for simple skills
- relatively poor for skilled performance or for somewhat sophisticated application
- no evidence that the successful skills are learned at school

Seeing a problem

- no data

Seeking solutions

- A very high percentage of student can correctly design procedures for performing certain experimental tests, but far fewer students (sometimes less than 25%) can do this for some other experimental tests.

Interpreting data

- Sizable percentages of students did NOT possess sufficient information about certain specific experimental procedures.
- typical data analysis behavior was demonstrated by a fair proportion of students but there is ample room for improvement.

Formulating generalizations

- no data

Building, testing, and revising a theoretical model

- no NAEP data
- no observations of this kind of activity were reported in the CSSE schools



DESIRED STATE

ACTUAL STATE

no data	50% negative	50-60% slightly positive	60-80% quite positive	80% highly positive
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(continued)

- (6) observations are accepted only if repeatable by trained people
- (7) there are a number of criteria involved for accepting a theory:
  - (a) logical coherence
  - (b) simplicity
  - (c) explanatory power
  - (d) predictive power
  - (e) potential for growth in developing scientific knowledge
- (8) theories give perception, i.e., observations
- (9) theories change over time
- (10) scientists publish results for others to repeat and react to.

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Strategies of inquiry

- (1) values
- (2) scientific inquiry
- (3) problem-solving & decision-making
- (4) evidence
- (5) use of logical thinking

- community pressure mitigates against it.  
- 50% do so outside of class. Many would like to. Teacher authority is strong.  
- many do know the strategies by & large, but will not use them when faced with a problem (NAEP item)  
- no data  
- little data

Safeguards & customs of inquiry

- not generally part of the classroom scene. are valued by only a small % of students, though most recognize their necessity for scientists.



DESIRED STATE

ACTUAL STATE 10-33

Program characteristics

Science taught as a rhetoric of conclusions rather than a process of discovery.

1. statements of outcomes w.r.t. inquiry
2. include assessment/evaluation
3. provide for study involvement
4. available to all, given intellectual match
5. content is consistent with inquiry outcomes
6. develop attitudes and examine values
7. history of science
8. text given less priority than investigation results
9. higher ed. levels explicitly value inquiry

- inquiry objectives exist at local level
- 8 states out of 42 had inquiry goals at state level
- perceived as difficult therefore seldom done
- little spontaneity at secondary level. Support peaked in 60's. Instruction tended to be didactic. Too much time and effort. Lacked equipment.
- no data
- doing text problems dominates over doing science
- no data
- no data
- the opposite was found
- higher levels tend to down-play inquiry

Program Dissemination/Adoption

- elementary teachers rely on peers for program information
- secondary teachers rely on journals and college courses

Program Implementation

Exposure

1. process/inquiry in all science courses
2. early and repetitious continuing in school
3. provide inquiry opportunities for study
4. content/process-not time on each, but how it is done
5. all students in an inquiry class, but outcomes must match student characteristics

- low priority to sc. ed. by superintendent. therefore, low financing. Exists in elementary but many cannot teach science; many do not try. Secondary has subject matter orientation
- "relatively quiet evangelism in the CSSE schools"
- "little inquiry experience in science classes"
- no data
- no data

Teacher Characteristics

1. possess inquiry skills, value inquiry

- teacher's philosophy has strong influence on teaching
- inquiry experiences are considered abstract & difficult by some teachers, and concrete and simple by others
- some expressed sympathy
- appears to be minimal, because of
  - (a) its difficulty
  - (b) competition for time by other pressures
  - (c) value of teaching facts. "Many teachers are ill-prepared"

DESIRED STATE

ACTUAL STATUS 10-34

- 2. possess teaching skills to teach inquiry
- 3. be models of inquiry
- 4. trained by doing inquiry

- 5. understand the nature of inquiry

Classroom Practices

- 1. atmosphere conducive to inquiry
- 2. variety of classroom practices appropriate to inquiry classrooms
- 3. self-initiated inquiry
- 4. use of the four goal clusters (person, society, discipline, and career)

Student Characteristics

Evaluation

- "many teachers are ill-prepared"
- "teachers do not set very effective role models"
- Teachers "took science classes, but didn't experience inquiry (therefore misunderstood it). NSF institutes likely facilitate inquiry and use manipulative materials. "Most teachers had not had adequate training."
- There have been some attempts to improve process skills in the education programs.
- Institutes can affect inquiry teaching material.
- some described tentative nature of science and how it works
- designing inquiry lessons more helpful than knowledge
- Inquiry is dangerous in discipline-problem classrooms. However, some teachers express the need for "hands-on" experiences, but this is usually for lower ability students. Most case study writers noted use of "hands-on labs", and the availability of facilities and equipment.
- no data
- science fairs only
- Goal clusters #1, 2, 4 are not sampled in NAEP i.e., no data.
- There are sufficient student problems (immaturity) to interfere with learning. "Inquiry teaching does not work for most students" -- second major reservation of teachers.
- Evaluation activities in schools are prohibitive against inquiry teaching. Inquiry achievement is difficult to assess. "NAEP has greatly improved on this point."

CHAPTER 11

THE STATUS AND NEEDS OF SCIENCE EDUCATION  
IN THE ELEMENTARY GRADES

Elementary Focus Group Members:

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## EXECUTIVE SUMMARY

Findings

"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 elementary science. Where are we now, almost twenty years later?

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

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 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 fictitious 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% - 30% who have heard of the NSF-developed curricula, she will not even know they exist. If 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 it 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."

What needs to be done? The recommendations are not simple, mutually exclusive, or dramatic. Instead, they are multi-faceted, systematic and long-range.

Since science in the elementary school is very much a part of the system (community, school and teachers) in which it must be taught, improving its chances for becoming a basic part of the curriculum involves working with all parts of the local system. Excellent curricula of various kinds are available. The NSF-sponsored projects and several recent commercial textbook series provide a rich set of choices from which a school system can select an excellent set of materials. At this time, funding of new curriculum development at the elementary level is not a high priority.

Although the teacher is a key ingredient in improving the teaching of elementary school science, simply to supply the teacher with a new curriculum and supportive training and then to ask her/him to use the new materials within a non-supportive system is futile. Two major activities need to be undertaken before effective implementation can occur. Those activities include the clarification of goals and the removal of barriers to quality science instruction.

It is important to clarify the educational goals of the community (parents and citizens), the administrators and the teachers. The philosophies and expectations of schools play an important and an increasingly observable role in the selection of curricula and the administration of schools. The citizens of a community very often have direct and indirect means of affecting in-school decisions. Well designed elementary science programs, such as those described

later in this report, can, if properly implemented, facilitate many goals of the local community, and this fact should be brought to the attention of local decision-makers. For example, if parents want students to learn basic skills, pertinent research findings and practical examples of ways in which elementary science improves student performance in these areas should be pointed out. If a local goal is to improve students' self-esteem, examples of how a quality science program can enhance students' feelings of self-worth should be described. If it is the goal of parents that their children "learn to think and solve problems," ways in which good elementary programs approach these goals need to be illustrated. If there is strong community support, some of the recommendations in this report will be easier to pursue.

From the three studies, it is possible to identify several barriers to effective science instruction at the elementary level. Concerns on the part of teachers and administrators were that: (1) there is not enough time to teach science; (2) science is difficult to teach and requires too much work; (3) there is a lack of supervisory leadership; (4) the budget is insufficient; and (5) facilities are not adequate for an activity-based program. Solutions to these problems must be found or the program expectations modified enough so that the barriers are no longer hindrances to the implementation of science programs.

Some of the barriers to effective science teaching rest with teachers. Many of them lack confidence, experience and sources of help in teaching science, especially an activity-inquiry mode. Hands-on inquiry teaching simply does not seem to work for many teachers. What interventions solve these problems? In-service, personal assistance and resource materials have proven successful in many cases in the past. It is believed that their efficacy will be greatly increased by applying them within the context of a systems-oriented model such as that suggested in this paper.

NSF institutes and local inservice courses have often trained teachers to use new and better materials and then have sent them into a system where the values and goals of the community were at odds with those of the teachers and the curriculum. When the well-documented barriers are added as another roadblock, it is no wonder so few quality elementary science programs have been implemented.

#### Recommendations

1. Given the situation described above, our major policy recommendation

at the elementary level is to increase efforts to improve the implementation of science programs at the local level.

2. Devise, field-test, and evaluate procedures to match a community's educational goals and the "expectable outcomes" of exemplary elementary science programs.

3. Conduct additional research to determine the extent to which the exemplary programs promote student growth in basic skills, problem solving, self-esteem, positive attitudes toward school and other common goals for general education.

4. 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.

5. It is recommended that selected case studies be conducted in 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.

6. On a trial basis (3-5 years), at a limited number of sites, provide significant funding for identifying and training resource and supervisory help at both state and local levels. 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.

It is important to understand that any implementation system must be "user-driven" rather than "producer-driven." Thus, materials, programs and other resources made available should not be limited to NSF-developed materials but should include any materials meeting the needs which become identified during the six steps described above.

## BACKGROUND

From a curriculum diet of sameness and uniformity in the early 1960's, elementary science has moved in the late 1970's to a state that reflects 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 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 resources available to the elementary schools in this country. Far from producing a national curriculum the result has been to almost insure that there will be no such entity. 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.

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. In this first phase of Project Synthesis, desired student outcomes were identified in four major goal clusters: (1) personal needs, (2) societal issues, (3) academic knowledge of science and (4) career education and preparation. These "desired outcomes" follow naturally as operational definitions of the four major goal clusters. They generally represent the goals and philosophies espoused by the science education community and are not meant to be either new or revolutionary.

The desired student outcomes were written based upon our 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 other secondary groups (physical/earth

science, biology, science/technology and society interactions and inquiry) to see if they fit within the elementary outcome statements. In virtually every case they did. To us, the elementary school was not 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. In addition to the desired student outcomes the desired states of "critical elements" of education which are necessary to support and help produce the student outcomes were also described. These elements included program characteristics, classroom practices, teacher characteristics, etc.

In the second phase of Project Synthesis, the actual state of elementary science education as described in four major sources was reviewed and the informational data organized according to these critical elements. To do so, the documents were carefully read and all statements and data related to each critical element were listed with a page reference to the original document. These rather lengthy lists were then synthesized into briefer narratives which are included here.

Because the data clearly indicated that the textbook or curriculum package was the major (and usually only) curriculum source for the elementary teacher. (CSSÉ 13:5; RTI 88), we reviewed the four most widely used elementary science textbooks (RTI B-44), three NSF-funded project materials and four more recent "NSF-influenced" texts to see the extent to which the desired student outcomes were represented.

Finally in Phase III the discrepancies between desired and actual states were summarized and recommendations made on how the discrepancies could be remedied. If new knowledge was called for to better understand a problem or a possible solution, specific research activities were recommended. The following sections present summaries of the working papers used by our group during the three project phases.

## DESIRED STATE OF CRITICAL ELEMENTS (PHASE I)

Sample Student Outcomes

## A. Goal Cluster I: Personal Needs

Students will:

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

## B. Goal Cluster II: Societal Issues

Students will:

1. Recognize that the solution to one problem can create new problems.
2. Use information and values to make decisions and evaluate the consequences for others in their community.
3. Recognize that some data can be interpreted differently by other people depending on their values and experience.
4. Recognize the ways science and technology have changed their lives in the past by changing the coping skills available to them.
5. Possess a sense of custodianship (collective responsibility for the environment over a period of time).

6. 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.

C. Goal Cluster III: Scientific Knowledge

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.

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

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

D. Goal Cluster IV: Career Education and Preparation

Students will:

1. Recognize that scientists and technicians are people with personal and human characteristics. (Teachers should use biographical sketches, personal knowledge, etc.)
2. Observe both sexes, minorities and handicapped represented in the written materials to encourage equal access to science-related careers.

Program Characteristics Necessary to Produce Student Outcomes

- A. Science programs should be interdisciplinary in nature (involving areas other than science).
- B. Genuine alternatives should exist so that real decisions can be made, real problems solved, and the consequences known or experienced.
- C. The problems presented to students should be definable, possible to accomplish, and should grow out of first-hand experience.
- D. Students should be actively involved in gathering data.
- E. Information that is presented should be clearly articulated through alternative modes; i.e., books, films, "hands-on" experience, etc.

- F. Information transmitted should be as appropriate as possible for the age level of the student and reflect how it was developed.

Appropriate Program Implementation

A. For Whom?

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

B. By Whom?

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

- (a) Sufficient knowledge and experience in science content and processes to feel confident when working with students.
- (b) 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.
- (c) 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.

C. In What Way?--(Instruction)

1. Instruction should be congruent with the desired outcomes and program characteristics above.
2. Instruction should reflect the aptitude and characteristics of students and teachers.
3. Policy should allow for an adequate amount of time committed to science to enable students to achieve the expected outcomes.
4. The actual time spent in instruction should be consistent with the policy.
5. The teacher's planning and interactive skills should facilitate and emphasize cooperative interaction between students without eliminating appropriate competition and individualistic interaction.
6. 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.

7. Because language grows in the context of experience, so the language of science needs to be learned in the context of experience.

#### D. Facilities

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

## ACTUAL STATE OF CRITICAL ELEMENTS (PHASE II)

Student OutcomesReview of Textbooks and Programs

Recognizing that published science curriculum materials represent the major determinants of the student outcomes in elementary science (CSSE 13:5, RTI 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 RTI, the four most frequently used text series at that time (1977) were selected for survey. The RTI study concluded that these four text series collectively comprise 22% of the curriculum in the primary classrooms and 40% 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 RTI survey, three of the curriculum programs funded by the National Science Foundation are currently being used in at least 8% 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 texts 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 four goal clusters in the established desired states and the five desired program characteristics.

Goal Cluster I. Student Needs: Content in the texts of Category A related to goal cluster I (student needs -- "what I need to survive") was primarily limited to portions of chapters on health-related information about the human body. A very limited number of instances of information about science in one's personal life was found. In texts at the primary level, the health and human body emphasis is generally quite explicit while at the intermediate level content in this area was either missing or only implied. Reading these texts leads to the conclusion that science content related to student need #3 (knowledge of self) was the only aspect

of student needs included in these texts.

An analysis of programs in Category B suggests that these NSF programs contain a desirable emphasis on helping students develop skills in producing and gathering knowledge that has a high personal relevance (student need #4), as well as on practice in learning to change their interpretations in the face of new data (student need #5). Some opportunity is also provided for students to practice decision-making and then living with the consequences. These programs have a notable absence of content related to consumer behavior (student need #1) and personal health (student needs #2 and #3).

In Category C texts, there is an explicit emphasis on content to help children understand and maintain their health (student needs #1 and #2). In two of these texts, data collection and interpretation skills are taught (student need #4). These topics are neglected in the other two programs.

In summary, content related to the "student needs" goal cluster ranges from explicit reference to slight hint. The emphases on the six subgoals show the following pattern:

Sub-Goal	Category A	Category B	Category C
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: The relationship of science to society is illustrated only occasionally in Category A texts. These illustrations are limited to technology and environment.

In Category B materials, except SCIS, emphasis on societal implications of science are absent. The life sciences materials of SCIS have a well-developed

sequence of concepts that enable the child to both understand and interpret interactions in his environment.

The emphasis on environmental understandings in the Category C texts was consistently high. Relationships of these understandings to societal needs were well illustrated in all Category C series.

In summary, content in science programs related to societal issues seems to be limited at best to learning about the environment with very few illustrations of how that information relates to society except in Category C materials. This pattern related to the six subgoals of societal needs was found:

Sub-Goal	Category A	Category B	Category C
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. Scientific Knowledge: In describing the knowledge we felt was most fundamental for elementary school children, we chose a set of four skills that enable a child to generate and interpret information gained from his environment. These skills include observation, categorizing those observations (classifying), quantifying those observations and interpreting observations. We also believed that students' interest should be taken into account in selecting content to be taught; e.g., his interest alone could be a sufficient reason for including a topic.

In Category A, the content is largely structured and presented with no intent to encourage students to generate either observations or interpretations of their observations. Both of these tasks, if addressed at all, are done by the author. The choice of topics is also that of another's perception of science with no documentation of effort to include topics based on children's interests.

In Category B, all three programs have a high focus on helping students generate and interpret scientific information. Although in two cases, the materials were trial-tested with students and modified subsequent to that trial, the topics were selected and made to fit classroom/student contexts. In one case, however, (ESS) student interest was explicitly considered in the selection of topics.

Category C programs include some in which information generation and interpretation skills are intentionally developed through the use of "lectures" on observing, etc. Based on information available, two programs include topics known to have been generated through student interest and two are based on author preference.

In summary, content related to fundamental skills and student interest show this pattern:

Sub-Goal	Category A	Category B	Category C
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 Knowledge and Preparation: Content which clearly addresses the human side of scientists as well as emphasizes equal access to science for all population groups was searched out. The human side of scientists was limited to a few short biographies in some texts, but they were either absent or easily avoided in most programs. The idea of equal access to science for minorities and women was limited to pictures or drawings showing both boys and girls as well as some minorities involved in the pursuit of science.

The obvious conclusion was that this goal cluster was generally neglected in all the texts we examined.

Sub-Goal	Category A	Category B	Category C
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, was 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% recognized the function of major systems in their bodies (C15C01) and 73% understood what would make the heart beat slowest (C15C04). 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%) 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% say they would stay home from a party when they have colds (C02A07-1).

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

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

Information produced by scientific research was recognized as being useful for keeping healthy by 91%, for deciding what cereal to buy by 50% and for choosing a toothpaste by 53% of the nine-year-olds (C010C2-1).

Goal Cluster II. Societal Needs: 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 (C02A05-1, C02A06-1). Approximately 90% of the nine-year-olds knew about simple acts that help or hurt the environment (C62C11). Fairly large percentages (80-90%) 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% of the 13-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% of the 13-year-olds could infer that it would cause more people to starve (C62C01). When 13-year-olds were asked to identify the results of eliminating a disease, 45% indicated it would increase the population, 37% indicated that it would increase food consumption, 31% indicated that it would reduce the reserves of natural resources and 38% recognized it would produce a greater need for recreation. We considered these results disappointing.

Goal Cluster III. Scientific Knowledge: In our discussion of scientific knowledge, we defined four basic skills as being essential. NAEP results related to these skills are described below:

Skill	NAEP Data
Generating Information/Observing	<ul style="list-style-type: none"> <li>- Most students (82% of 9-year-olds) can order a sequence of simple events in a change (C56C04)</li> <li>- 68% can recognize differences in information from people with different handicaps (C56C03)</li> <li>- A high percentage (53%) would do an experiment to find out the answer rather than ask the teacher (C52C01)</li> <li>- Ninety-one percent of 9-year-olds can read a grid map, but few (30%) can describe change in location based on a map (C54C10, C54C11).</li> </ul>
Categorizing Observations or Classifying	<ul style="list-style-type: none"> <li>- Most 13-year-olds (66%) can use a classification scheme (C55C01). Few 9-year-olds (26%) can generate categories of classifications when given the objects (C55C04).</li> </ul>
Quantifying Observations or Measuring	<ul style="list-style-type: none"> <li>- Many 9-and-13-year-olds have taken measurements many times in solving problems outside of class (C04A04).</li> <li>- About two-fifths of 9-year-olds and more than one-half of 13-year-olds can accurately estimate the length of an object in metric units (C54C01, C54C08, C54C12).</li> <li>- Ninety-three percent of 9-year-olds can read a thermometer correctly (C54C13).</li> </ul>
Interpreting Observations	<ul style="list-style-type: none"> <li>- Few (31% of 9-year-olds) recognize regularity in nature, e.g., phases of moon (C52C03).</li> <li>- Generally students can construct interpretations based on concrete experiences, but this is not so with second-hand information.</li> </ul>

(continued next page)

- Generally, most 13-year-olds can read graphs and tables, but fewer can successfully interpret graphs (especially line graphs).

Goal Cluster IV. Career Education and Preparation: 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% said it would be fun. About one-fourth of the nine-year-olds, however, were already feeling negative about this career choice (27% felt it would be too much work, and 20% felt 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%). Only 42% felt a career in science would not take too much education, and half felt it would not be too much work (RC02A03).

In terms of recognizing scientists and technicians as people with personal and human characteristics, there was almost no data available for the nine-year-olds other than only 14% saw science as a "lonely" profession (RC02A08). Even with the relatively low interest of the 13-year-olds in science as a career (less than 50% wanted to know more about science as a career), 81% would like to see scientists in action (RC02A01), perhaps indicating an interest in scientists as people.

There was 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% of black students, compared to 74% 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.

### Interdisciplinary

The extent to which other disciplines are included through reading and activities in the three categories of texts varies considerably. Category A texts contain virtually no discussion of content other than science. Category B programs contain a high amount of interdisciplinary material (particularly ESS and S-APA). Category C programs seemed to follow the example of the NSF programs in this area.

<u>Category A</u>	<u>Category B</u>	<u>Category C</u>
Low to None	High to Moderate	High

### Alternatives Exist So That Real Decisions Can Be Made

The Category A books display a highly structured, non-inquiry approach to learning. Few, if any, alternatives for student decision-making exist in the materials. Where there are questions or laboratory suggestions, the answers or results are almost always provided on the next page of the text; or the activities are considered optional and never discussed.

In Category B, the programs depend very heavily on laboratory activities in which students are usually given some choice of procedures or techniques that require decisions on their part.

The Category C books are mixed in this dimension. One series follows the lead of Category B very closely, but the others present few opportunities for students to answer questions in an open manner.

<u>Category A</u>	<u>Category B</u>	<u>Category C</u>
None	High	Low to High

### Problems Definable Through First-Hand Experience

Category A content selection appears to be based upon the structure of the discipline. Concepts are usually presented to students and then investigations are inserted to demonstrate a point. Student experience or needs do not seem to be considered in the selection or presentation of the content.

In Category B, the investigations are designed to lead to the concept or process desired or selected. ESS units were developed by observing student responses to materials and ideas; whereas S-APA and SCIS were piloted to insure student success and interest in a pre-determined process or content structure which ultimately determined the general selection of student experiences.

In Category C, the series exhibit a mixture of Category A and B characteristics.

Category A	Category B	Category C
Low	High to Moderate	Moderate

There seems to have been a clear shift from teacher-given and teacher/text-solved problems to greater student involvement in generating and resolving problems.

#### Data Gathering

The extent to which students are actually involved in collecting data varies widely. In Category A programs, suggestions for hands-on activities are made in separate and easily avoidable supplemental materials. In Category B, students' involvement in data-gathering is an absolute essential that cannot be avoided. Category C programs (with one exception) show a very high level of student involvement. Thus, the emphasis on direct involvement of students in hands-on data-gathering was initiated with the NSF materials and appears to be continued in the post-1977 texts.

#### Alternative Modes

Evidence strongly suggests that a variety of modes for sharing information enhances the impact that information will have on students.

In Category A materials, the mode of presentation is essentially books with a few supplemental films. Category B materials rely almost exclusively on hands-on materials. In Category C, there is a range from reading only to a variety of modes.

#### Appropriateness to Developmental Level of Students

Content information should reflect how the student at an age best learns. From the perspective of the cognitive development of a child, the materials in Category A show no evidence of this concern. The cognitive development of the child was a significant factor in the selection of content of materials in Category B and this also appears to be true of Category C.

In summary, there has been a substantial shift in the character of science programs toward the desired characteristics which formed our perspective in Phase I.

Sub-Goals	Category A	Category B	Category C
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

### 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 (OSU 16, 93); thus, one might infer there has been little effective dissemination. The most common teaching technique is lecture-discussion (OSU 98; RTI B-60; CSSE 13:89). The time spent in science instruction today is virtually the same as three years ago (RTI B-6). Most teachers (61-92%) have never heard about new science curricula (RTI 38). Almost one-fourth of the schools use texts written prior to 1971 (RTI 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 (RTI 81) and where teachers are hungry for change (RTI 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 (RTI 73, B-11). Science resource staff are also used significantly (OSU 94), although only 22% of districts have science resource people (RTI 39). NSF institutes and related programs were helpful (OSU 13), but reached no more than 5% of teachers (RTI B-8). In addition to teachers, some resource staff and NSF institutes, principals are seen as significant potential sources of information although only 9% of them feel they have an adequate background and 20% feel they are "not well qualified" to assist in science (RTI 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 RTI survey reports that 31% of the elementary school districts used one of the NSF programs (RTI 29). Another report indicates that in 1975, 17% of the elementary students were enrolled in schools using SCIS, 12% ESS, and 20% SAPA (OS 18). This can be compared to the usage of the three projects reported by teachers (RTI 83). This report indicates that 20% of K-3 teachers are using federal programs and 27% of 4-6 teachers. Larger districts with greater per-pupil expenditures are more likely to use the NSF materials (RTI B-32).

Teachers, who do not feel confident in their knowledge of science, are the major selectors (RTI 99) and determiners (CSSE 13:5) of the elementary science

curriculum. Most teachers, 46% at K-3 and 56% at 4-6, use a single textbook/program (RTI 89; CSSE 13:59). Pressure groups and public understanding of science affect textbook selection (OSU 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 (CSSE 12:8, 16:7, 12, 3E), and many feel it requires too much work (CSSE 12:4, 15:7).

The "back-to-basics" movement has had a significant effect on the schools in recent years (CSSE 13:34-45) 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 (CSSE 18:55). The "socialization" responsibility of teachers is a major influence on what is taught and how (CSSE 16:7). Socialization goals lead to emphasis on (1) extrinsic motivation, (2) attention to directions, (3) homework and (4) testing (CSSE 16:21). Socialization is more powerful than scholarship (CSSE 16:23) and may explain why teachers react negatively to innovation (CSSE 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." (CSSE 16:23).

### Program Implementation

#### Teachers

Teachers mentioned many "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 course work after they graduate, and do not study science on their own" (OSU 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 (RTI 15:7). Others feel they don't have time for hands-on science (CSSE 15:7).

### 3. Traditional text teaching.

It is apparent from the studies that most science is taught through textbooks (RTI 13:5). The source of knowledge authority...was not so much the teaching--but the textbook (CSSE 13:59). Teachers are satisfied with programs/texts they now have (RTI 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" (CSSE 15:7).

### 4. Lack of dissemination of alternative science programs.

Most teachers (61% to 92%) have never heard about new science curricula (RTI 38). About one-fourth of the schools use texts written prior to 1971 (RTI 95). Further, in 1974 only 14% 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 (OSU 191). This information is supported by the fact that 30% of K-3 and 38% of 4-6 science teachers stated they did not receive adequate assistance. Sixty-one percent of K-3 teachers and 52% of 4-6 teachers rated other teachers as being very useful as sources of information, while 27% and 21% of K-3 and 4-6 teachers respectively rated specialists as very useful and 33% and 23% rated principals as very useful (RTI B-117). Other data indicate that only 22% of districts have a supervisor available with as much as 75% of the time devoted to science (RTI 39). It was found that fewer than 25% of those K-6 science supervisors attend national meetings and only 12% belong to NSTA (RTI 42-43).

6. Lack of budget and facilities.

More than 40% of the K-3 teachers listed lack of equipment, money to buy supplies, storage space, and paraprofessional help as areas where improvement is needed. ~~The 4-6 teachers listed facilities (42%),~~ equipment (55%), money for supplies (57%), storage (58%), preparation space (50%), and small group space (54%) (RTI 136). There is near universal agreement that school dollars for science are declining (OSU 142; CSSE B-2). While 40% of schools have required instruction in science (RTI 20), only 16% of the schools have a known budget for science (RTI 126). Despite the fact that funds are short, a poignant question asked "is whether more money would buy better education" (CSSE B-17).

7. Lack of paraprofessional help.

Forty-eight percent of K-3 teachers and 56% of 5-6 teachers reflected this concern (RTI 136).

8. Lack of prerequisite skills.

The lack of training in science disciplines was perhaps the biggest obstacle to elementary programs (CSSE 2:22). Nearly two-thirds of elementary teachers feel "very well qualified" to teach reading. Twenty-two percent feel qualified to teach science, 39% social studies and 49% math" (RTI 138). In another survey elementary teachers' perceptions of their qualifications to teach science were: not well qualified (16%), adequately qualified (60%), and very well qualified (22%) (RTI 142). Another source states most elementary teachers have not participated in "intensive institutes" (OSU '3). On the other hand, district and state personnel tended to describe the barriers to effective science teaching as the fact that science was seen as "less important" than other subjects with a lack of teacher interest and inadequate preparation to teach science (RTI 10). Teachers specializing in science are rare in the primary grades. Inadequate preparation for teaching is considered a problem by principals (RTI 161). Lack of teacher interest in the particular subject is considered a problem only in K-6 (RTI 161). One principal stated: "I have to almost force someone to put the science kits in their classes. No one wanted anything to do with it. They got their minimum time allotments in." (CSSE 10:19).

"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." (CSSE 19:3).

### Instruction

Even though 95% of the nine-year-olds reported in the NAEP survey that they have some science in school (RC01E05), there is evidence that a significant number of teachers teach little or no science at all (CSSE 13:16) and that science K-6 is nothing more than show and tell (CSSE 5:28). There is data indicating that most of the science teaching that does exist at the elementary school level is lecture-discussion (with some demonstration) centered around a textbook (RTI 5, 6; OSU 32; CSSE 5:10). Very little use was being made of NSF-funded, materials-oriented programs (RTI; OSU). It was found that more time is devoted to those science classes which use NSF-sponsored materials than to those which do not use these materials (OSU 32).

Teachers felt that appropriate social and academic behavior was equally important to academic achievement in science and that students "need help" in attending to their tasks (CSSE 18). For these reasons and others, inquiry teaching was seen as difficult and not consistent with the realities of the classroom by classroom teachers (although a good idea in theory) (CSSE 10).

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% felt encouraged to give their own ideas. In addition, 93% said it felt good to find something out on their own. However, in contrast to those feelings, 61% of the nine-year-olds said they would rather be told an answer than have to find the answer on their own, and 77% do not like questions to which they do not know the answer (RC01T03, RC04A08). Unfortunately, only 57% of the nine-year-olds wanted more science.

There are three major areas of discrepancy between the desired state of elementary school science outlined in Phase I and the actual state described in Phase II;

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 the desired program 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 systematically 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 the 1950's, parents desired scientific, technological and engineering expertise. Schools responded and teachers emphasized a new set of scholarship goals. With intense disfavor today, parents are noting the permissive atmosphere of schools, the astronomical increases in costs and the steady decline in performance of students. Their conclusion is that schools are not doing what they want. But what do they want? Parents describe their "wants" on shopping lists which usually include some of the same significant desires.

Discipline and back-to-basics are at the top of the list. 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 (Chicago Tribune, March 7, 1979) headlined a report that while the 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% of the parents, is defined by many to include respect, manner, politeness, discipline

The Chicago Tribune, March 7, 1979, stated,

"After a decade of declining test scores, many parents, college admission offices and employers are pressuring the schools to sweep out the frills and return to teaching basic subjects."

SAT average scores have been declining since 1963. HEW recently reported that 13% of the nations 17-year-old high school students are "functional illiterates", meaning they cannot perform simple tasks such as reading newspapers or road maps.

In summary, parents are making their desires known; they are demanding that schools teach the basics to all students regardless of their background and interest. Parents are equally insistent upon schools keeping children occupied during the school week, providing them with an array of salable skills and doing so in a structured non-permissive environment.

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 (CSSE 15:5). The elementary science program described in the Desired State section 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 a inquiry-oriented science program. When parents' demands show a shift to these basic goals, school management support for elementary science simply disappears (CSSE 17:8).

More than 70% of the elementary principals believed that back-to-basics were the important issues and the 3 R's must have priority (CSSE 18:55). School administrators at the state and district level consistently see science as "not as important" as other subjects (RTI 10). The mandate school administrators see in the parental concern is the need for schools to contain the students, control their behavior and provide some salable skills and knowledges in basic fundamentals of reading, writing and arithmetic. Socialization is the priority, and if time permits, scholarship can be tolerated.

The teachers are the final arbitrators of what actually happens in the classroom. They listen carefully to the school managers' translation of these pressures. Within the context of their science classroom, they decide how science fits what they must do. They are keenly concerned about how to get students to perform well and live up to the community expectations of them as teachers (CSSE 15:14). Performing well clearly means meeting the demand of the social system first (16:23), the needs of the individual students next (OSU, 147) and the scholarship needs of science last (CSSE 15:4).

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 (CSSE 15:4). Such instruction appears undisciplined, unproductive, and certainly not work-like (CSSE 12:8). Such instruction has not helped students get ready for later schooling (CSSE 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 (CSSE 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. Formal instruction that enhances socialization goals while enabling teachers to control the students does seem the "best fit" response to today's message from parents. How can we as science educators respond in intellectually honest ways to the school situation?

First, we need to clarify both the goals and their priorities as seen by 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.

Second, we need to identify the programs and teaching methods, the outcomes of which are congruent with the goals of parents, school administrators and teachers. We need to find ways in which science education goals become their goals, 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.

Third, we need empirical data that will show 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 -- and only in this way can science be an essential, valued part of the schooling of children.

#### Reducing the Barriers to Desired Elementary Science Programs

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 structure of the parents and administrators and the training, interests and value structures of the teachers.

Are the lack of time or 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.

Research is needed to sort out real barriers from manifestations of a value system that says science is not important for elementary students. It is important that research be carried out where there is clear evidence of community and school system support. One possible method of research is to perform case studies which focus on a variety of districts across the country where exemplary science is being taught in the elementary school. By looking at the successful implementation of programs, strategies will be identified for reducing the barriers or modifying programs to meet the constraints present. Such research can answer questions such as: Did supervisory leadership play an important role? If inquiry-based science is valued, how much preparation is needed by teachers?

### Improving Instruction

Instruction in science in the elementary school is falling short of the "desired states". Although the pressures and values of the public and an array of "barriers" are in large part responsible for this gap, it is the school personnel (principals and teachers primarily) who ultimately have the responsibility and will be the change agents for improving science education. Presently, school personnel are generally not delivering effective science education in the elementary schools.

If science were seen as highly important by parents and school administrators, there would still be a problem. Barriers which would still stand in the way include traditional textbook practices, budget for materials and systems for handling them, lack of time for teachers to prepare and teach science, etc. If these barriers could be changed or overcome, there would still be a problem. The school personnel (primarily the principal and teachers but also aides, custodians, secretaries, and even bus drivers) represent constraints which need to be dealt with as well.

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 desired 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 (RTI 106; OSU 32, CSSE 16:7;

CSSE 18:8-9, 19).

In terms of teacher confidence and interest, school districts and state departments of education reported that teachers perceived science to be less important than other subjects, that there was a lack of teachers' interest in the area, and that teachers were inadequately prepared to teach science (RTI Chapter 10). The Case Studies in Science Education reported a deemphasis of science instruction with many elementary teachers ignoring it completely (CSSE 13:51). In one of the case studies, a teacher asked the class, "How do we learn?" and the total class reply was, "We learn by reading!" The lack of interest on the part of teachers was reflected in National Assessment science data for nine-year-olds. When asked if their teachers "really liked" science, sixty percent of the nine-year-olds marked, "I don't know" (RC01T03). Only six percent of the nine-year-olds selected science as favorite subject in school and only eight percent listed science as their second choice, while 60 percent of the nine-year-olds listed either English or math as their first or second choices (RC01E01). These results probably reflect the interests of the teachers; certainly it is in agreement with the data from teachers. For science to become effectively taught, attitudes of school personnel toward science education will have to be improved. For teachers to use a materials-oriented, inquiry approach to science, they will have to become convinced that it is worth the trouble, that it can work in their setting, and they have the skills to do the task.

The data indicate that elementary teachers will increase their use of inquiry/process-oriented science lessons when exposed to the appropriate training (OSU 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 (RTI 118, 120). More time is devoted to science in classes using NSF-sponsored materials than in those not using such materials (OSU 32).

To overcome this access problem at least two steps are needed:

1. Extensive resources should be provided for upgrading the undergraduate and graduate programs in elementary science education.
2. 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. Massive support should be provided to universities, states, consortia of school districts and individual districts to provide local inservice courses that support the desired quality of instruction. Where possible, inservice should be associated with district level change processes, and combined with other efforts to improve elementary science instruction.

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). The teacher, of course, is key. The teacher has the final say on the quality of the program in a given classroom of students.

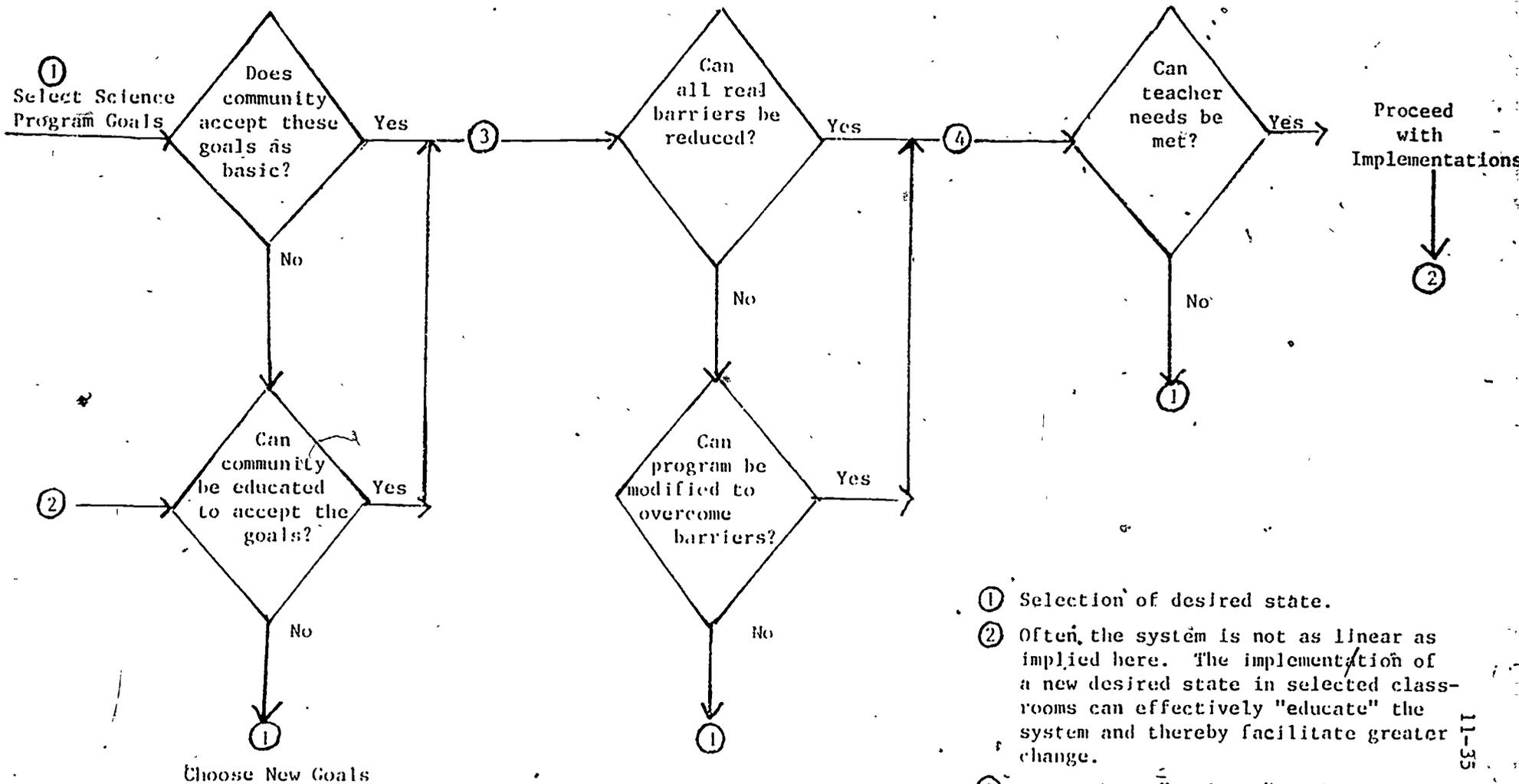
Because all levels of the school system are involved, the entire system should be attacked in an organized fashion. There is evidence that the institute approach to the training of teachers and administrators is effective, but there is also evidence that sending teachers back to a classroom in a school 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 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.

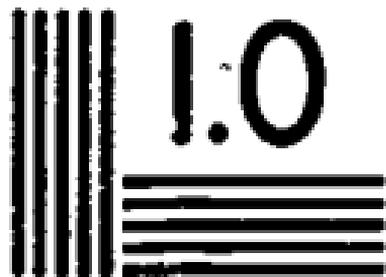
Most of the above recommendations can fit logically into a systems approach such as that illustrated in Figure A. The essential piece still missing is the resource person to create and carry out the plan. To solve this problem it is recommended that extensive funding be provided at the state or local level to investigate the effectiveness of such a systems approach. Funding should be provided for resource people and programs to follow the recommendations of the community, school and teacher levels. A national training program for the resource persons would be an important prerequisite to installing the process at the local level.

Where can support for these recommendation be found? The present policy and program of the NSF are not designed for this kind of systematic comprehensive attack on the problem. The current NSF research programs could be modified and expanded to set up pilot programs to determine the effectiveness of the recommendations.

SYSTEMS APPROACH TO IMPLEMENTING  
THE EXEMPLARY SCIENCE CURRICULUM AT THE ELEMENTARY LEVEL



- ① Selection of desired state.
- ② Often, the system is not as linear as implied here. The implementation of a new desired state in selected classrooms can effectively "educate" the system and thereby facilitate greater change.
- ③ Research on "realness" of barriers.
- ④ Identification of teacher needs.



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Assuming the results of such research are positive, where do we go next? As indicated earlier, extensive new elementary science curriculum development is not needed. The training of individual teachers in institute-like settings is an endless task and, as argued earlier, if it is done without the total systems approach the results are extremely limited.

If elementary science teaching is to be improved, what is needed is massive support of implementation activities. The last fifteen years of elementary science education has been largely devoted to curriculum development. The next fifteen years should be spent on implementation. If the NSF is not prepared or capable of financing such an endeavor, other agencies such as the Department of Education should be encouraged to do so.

CHAPTER 12

INTERACTION OF SCIENCE, TECHNOLOGY, AND SOCIETY  
IN SECONDARY SCHOOLS

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## PREFACE

The national awareness of the interactions of science technology and society has been slow in coming, even though they have affected political, social, economic and technological decisions through the ages. Most people are aware of these interactions only superficially, and yet major problems and major decisions affecting their lives are a direct product of such interactions.

The teaching of science has undergone significant changes during the second half of the twentieth century. In the early fifties, physics and chemistry courses emphasized technical (though not societal) issues. The solvay process, the steam shovel, the automobile, etc. were added to the chapters of chemistry and physics books as "practical applications," and for a time the pure physicists and chemists feared that texts would become all applications and no physics or chemistry. In the post-Sputnik era, the pendulum swung the other way toward presentation of pure principles with little or no attention to real world applications or societal implications, and students began choosing other subjects in place of physics and chemistry. This meant that the college-bound student has been largely isolated from the technological, as well as the societal, aspects of science while in high school, and his only contact with societal issues of science usually came from social science teachers who tended to emphasize the negative aspects of science, if they mentioned technology at all.

It was the responsibility of the Science/Technology/Society Focus Group of Project Synthesis to inspect the major data sources of Project Synthesis for indications of the current status of technology education in pre-college science education programs. The ultimate goal of this activity was the formulation of policy-relevant interpretations and recommendations appropriate to a variety of "audiences" involved in the science education enterprise.

The first tasks of the group were to develop a working perspective and to identify goals of technology education. The product of this first phase of the project was an operational definition of the domain of technology education stated in specific, concrete terms and relying primarily on examples. This domain is presented in the first major section of this report, "The Desired State of Technology Education."

During the second phase of the study, the actual status of science programs as they pertain to technology education was determined based on the Project Synthesis data base. This "actual status" is described in the second major section of this report, while the implications of the findings and subsequent recommendations (the products of the third phase) are presented in the final section. This report and those of the other four Project Synthesis focus groups constitute the working documents from which the final Project Synthesis reports were derived.

## THE DESIRED STATE OF SCIENCE-TECHNOLOGY-SOCIETY (STS) EDUCATION

Introduction

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 (e.g., 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.

This section of the report is a statement of the desired state for the teaching of science-technology-society issues at the present time (1979). 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 concerns at this time. These areas are:

- A. Energy
- B. Population
- C. Human Engineering
- D. Environmental Quality
- E. Utilization of Natural Resources
- F. National Defense and Space
- G. Sociology of Science
- H. 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.

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. Subsequent sections briefly describe some of this focus group's thought concerning more general educational concerns such as program characteristics, dissemination, adoption and implementation.

#### Desired Student Outcomes

##### 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.

A. 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 "trade-offs" associated with decisions involving his/her own energy conservation plan;
3. Apply rational processes of thought to a proposed solution to his/her problems related to energy resources and their efficient use.

B. 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);
3. Describe the impact that technological advances has had on the family unit in different type communities and predict future impact (e.g., transportation, new and obsolete careers, improved health services).

C. 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., abortion, organ transplants, cloning, gene 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, gene engineering, behavioral modification).

D. 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.

E. 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/describe 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).

F. 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, "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.

G. 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.

H. Effects of Technological Developments. Science education programs should provide the individual with an understanding of the effects of technological developments. 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.

A. 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 underdeveloped countries (e.g., developed countries use more energy and material resources per capita than underdeveloped countries);
2. Describe the role of interest groups and the various trade-offs associated with the development of an energy plan; and
3. Evaluate the short and long range effects of proposed solutions to the energy problem.

B. 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 has on service elements of the society (e.g., energy, transportation, health care, supplies);
2. Describe how overpopulation will effect the environmental quality (i.e. 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).

C. 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 techniques 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 of some persons caused by techniques of human engineering.

D. Environmental Quality. Science education programs should provide the individual with the background necessary to recognize variations of the acceptable environmental quality of his/her community, state and nation, as well as to maintain and/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 cause reduction in 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).

E. 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 that of third-world countries; and
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 his/her 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.

F. 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).

G. 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.

H. Effects of Technological Developments. Science education programs should provide the individual with an understanding of the impact of technological developments on society, and enable them 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 pay-offs (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 pay-offs 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 examined by testing laboratories.

Goal Cluster III - Academic Knowledge of Science

Science education programs of the community should insure the continued development and application of scientific knowledge by maintaining a "critical mass" of fundamental scientific understanding in the American public.

A. Background Knowledge. Science education programs should be included as an essential to general education and provide individuals with the necessary process skills and knowledge of science and technology necessary to:

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

2. Pose and answer problems confronting the individual and/or society by applying scientific knowledge; and
3. Evaluate scientific knowledge, research and technology.

B. 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 has become obsolete and how this has affected society;
2. Identify examples of breakthroughs in scientific knowledge and/or technology and how this has affected society, and
3. Describe how the potential and the limitations of science and technology are affected by research and societal values.

C. 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.

A. Career Opportunities. Programs of science education should provide the individual an appreciation for (of) the 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).

B. 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 interest 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 necessary academic preparation and related field experiences necessary to be employable in the chosen career.

C. 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.

#### Desired Program Characteristics

##### Teachers

In an ideal situation, science teachers would believe that they have responsibility for enabling their students to achieve learning objectives such as those outlined earlier in this chapter. Their evaluation of the materials they utilize would reflect the importance of the STS domain, and they would actively seek science textbooks and other student resources which include topics in that domain. Due to initiative by teachers, district and state coordinators and others, teachers would be aware of existing materials which pursue such objectives, and would influence their schools to offer course options which stress STS topics. Teacher preparation would include STS related courses, and inservice activities would keep teachers up to date on emerging STS topics.

### Classroom Activities

The desired science program would use a variety of instructional modalities (e.g., readings, laboratory activities, out-of-school experiences, lectures, discussions, films and simulations) which provide students with the opportunity to examine technological developments and their effect on individuals and society.

Students would have the opportunity to examine technological developments and experience effects firsthand when appropriate and convenient. They would also have the opportunity to experience results through laboratory experiments, simulations, and various media presentations. When a topic is unfamiliar or beyond the ability of the teacher to present personally there would be opportunity for the students to glean the outcome through the medium of direct interaction with experts in the field when possible or through film, filmstrip, television, etc.

### Course Offerings and Student Populations

In the ideal situation, all students would have the opportunity to achieve objectives such as those outlined earlier. Standard science course offerings, both required and optional, would include STS topics. Ideally, mainline texts used would include STS topics integrated with more traditional science topics. If such texts were not available, supplementary materials would be found to fill the gap. In advanced courses such as chemistry and physics, such topics would be selected to help prepare responsible, socially conscious scientists and engineers. For students unlikely to enter engineering fields, less rigorous STS related courses would be available.

## ACTUAL PRACTICE REGARDING STS EDUCATION

Overview

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, as defined by our group, in currently available textbooks. We 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. In order to deal with this problem, it is necessary to consider those aspects of the societal and school context which appear related to the problem.

### Contextual Factors Affecting Science Education

#### The Social Setting

Society is in the midst of change. Although, change is a normal on-going process which is not unique in and of itself, it amplifies the stress conditions placed on the interface between elements of the social structure. Such interface areas occur between various components of the culture which can, for the most part, be identified as separate elements. The biological/ethical questions are examples of such interfaces. Similarly, the problems of short term vs. long term goals are sometimes a function of interface. Historically the schools have played important roles in reducing tensions which occur at such interfaces. However, current change of society may be more rapid than can be accommodated by the traditional mechanisms within the schools.

#### Schools in Changing Environments

Programmatic decisions in schools are normally left to the direction of professionals. However, when some students complete school only to demonstrate an inability to read, write or do basic computations, the public

confidence is shaken. It is not difficult to explain the trend to greater public control of public institutions. In this situation, the broad purpose (long term goal) of education is easily rejected to insure that children develop skills (short term goal) for getting high paying jobs. The result is a narrowing of the perspective to one that is broadly accepted or understood. The "back-to-the-basics" movement is a case in point. Certainly an understanding of the "basics" is important but undue emphasis can cause a limiting of the knowledge that is learned.

This limiting of knowledge can be seen in the well-intentioned move to establish proficiency levels which is closely linked to the back-to-the-basics movement (CSSE 12:17; RTI 31-33). Minimum competency levels tend to foster a belief in a certain completeness that is certified upon passing the minimum levels of proficiency which tend to reflect low-level cognitive skills (CSSE 14:33). Thus, teachers and courses emphasize low cognitive outcomes at the expense of affective outcomes, processes, or thinking (OSU 207). Similarly, the emphasis on basic skills and minor applications precludes the instruction of the discipline for use in problem solving and analytical thought (CSSE 12:11-12; 14:34; 18:53). The instruction of inquiry skills is often considered to be in direct conflict with the "work ethic" (CSSE 12:7) which is inherent in the back-to-the-basics movement; that is, "hard work is good work" (CSSE 16:16). Furthermore, to teach self-direction skills or the value of questioning is in contradiction with the authority/subordination ethic (CSSE 12:11; CSSE 16:6, 33; CSSE 19:5, OSU 117). The result is that the teaching of inquiry using strategies of inquiry is almost nonexistent (CSSE 12:4-7) and the evaluation process becomes testing for the basics (CSSE 15:15).

The social emphasis on career education/training seems to have had a significant impact upon how students view their education. Students seem to feel that knowledge should have immediate application or clearly relate to job opportunities (CSSE 18:43, 104); minimum requirements become viewed as merely hurdles to be overcome (CSSE 13:26; 15:13, 29). In such situations the student is seeking the grade or grade-point average, and this tends to discourage students from taking more rigorous courses (CSSE 12:18; 15:19, 28, 30, 31). This reaction may be more prevalent among the college bound (potential scientists and future leaders) than for the noncollege-oriented students.

Hence, students and parents think of education as preparation for the career (CSSE 17:21). Parents believe that schools should be teaching job-oriented knowledge and skills (CSSE 18:43). Education and the schools are expected to provide curricula related to job training or vocational preparation (CSSE 12:22). Courses which provide "subtle" education are not easily identified with job preparation. It is not readily apparent to the student how science contributes to career development (CSSE 12:23-24), however, it seems that technology education could be more readily identified with making career choices.

In an era where career preparation is a significant motivating factor, students do not have adequate career information at their disposal. It is believed by many teachers that an education in natural science and mathematics is useful only when preparing for technologically based careers (CSSE 12:24). Furthermore, there is evidence that suggests that school personnel are unaware of what the job market is (CSSE 12:25).

In summary, the social setting for contemporary education appears to be one which fosters short-range objectives which have immediate or specific rewards. There is little attention to long range purposes which lend themselves to long term goal setting. Changes in curriculum or course offering in the schools must take this phenomena into account. The public confidence once enjoyed by the school and education is being seriously threatened.

### Effects of Technology

While the schools are being subjected to increased public control, technology appears to be developing in an uncontrolled direction and at an unchecked rate. The public seems to have little appreciation for the direct influence of technology on the lives of individuals. Furthermore, the lack of public awareness of technologic power results in a false feeling of independence while building a complex web of dependence.

Since the beginning of time the application of knowledge to improve the quality of life and to remove the drudgery of labor has been an ongoing, though not necessarily a conscious process. Technology, whether it be the development of road-building machines or apparatus akin to artificial intelligence, has continued to change the course of human life. The "technology" revolution is still in motion and there is no indication that the momentum

will decrease. In fact, the increased alliance of science with technology over the past six decades has resulted in an unprecedented growth of knowledge and technological development. The symbiotic growth of science and technology can be discussed historically, but such an analysis is not important here. It is, however, of interest to note that history clearly shows that technological development parallels the growth of America but does not reflect the complex interactions between society and science/technology.

### Goals and Practices Related to STS Education

#### Stated Goals

Many educators appear to recognize the importance of students understanding the relationship of science and technology to society. It is not difficult to find documentation for this concern in professional journals such as The Science Teacher and Science Education as well as in other professional group publications such as AAAS Guidelines and Standards or NSTA's Theory into Action. Recommendations are continually being made calling for increased attention to societal issues such as those which constitute the themes of the STS focus group (population, energy, etc.).

The Ohio State Report indicated that:

"A number of concerns have emerged from the curriculum development of this period (1955 - 1975). Some materials are being produced to provide solutions to some of the problems. Among the concerns were those previously mentioned, the lack of practical or applied science and the lack of emphasis on the difficulty of the materials produced (including content and reading), lack of interdisciplinary emphasis, lack of emphasis on technology, and continued lack of articulation in curricular materials" (OSU 30).

Also, according to the same report:

"The objectives for teaching secondary school appear to be in transition. Increased emphasis is being given to

environmental concepts, societal concerns and world problems, decision-making and "interdisciplinary studies" (OSU, 21).

### Actual Practice

Unfortunately, there is little evidence to indicate that any more than an extremely small number of students are being exposed to courses or materials with such emphasis (RTI: 58, B23). There is even less evidence that STS issues are being incorporated into traditional science courses, since such courses are largely textbook-oriented and the most commonly used texts ignore STS topics. Thus, there is a great discrepancy between stated goals and actual practice with respect to STS education.

Although the three NSF studies examined by Project Synthesis were not intended to look specifically at whether or not the goals of the STS focus group are being achieved, there are numerous findings in the reports of those studies from which it may be inferred that understandings about science-technology-society are generally not a part of science education programs. The following quotes from the CSSE Reports illustrate this point:

"In school settings greater emphasis was given to reading and arithmetic and to the results on minimum competency testing aimed at the basics; less emphasis was being given to science, math, and social studies concepts and relationships. Teachers were willing to make this trade-off, saying that youngsters would not understand complex ideas until they could read them." (CSSE 19:3).

"As seen by most people in the schools, science education has no more alliance with mathematics education and social studies education than it has with English education. Science was seen by many to be the subject matter of physics, chemistry, and biology; and perhaps astronomy, botany or geology sometimes mixed together as general science." (CSSE 13:17).

"The science curriculum of the school was -- in operation more than by definition -- taken to be a set of knowledges and skills rooted in the academic disciplines. It was to be shared in common by all students who would undertake the study of science." (CSSE 19:4).

"Still, the effective emphasis was toward education of future scientists -- a small minority of all students who take science courses." (CSSE 19:4).

"Science and the social sciences are seldom being taught in an interdisciplinary fashion. Perhaps they are too hard to teach that way." (CSSE 19:35).

"With perhaps an exception or two in the case of environmental education there were essentially no interdisciplinary efforts in the schools of the study." (CSSE 19:3).

#### Basic Problems

In looking at the data, we saw three basic problems emerging. These problems affect all classes of students; the "academic elite", the "mainstream", and the "non-academic. These problems are discussed below.

Problem 1: The basic knowledge and processes of technology and their relation to society are not being taught to many of the future leaders of society. Furthermore, these students are not being afforded the opportunity to learn of the science-society issues important in today's society.

It appears that college-preparatory science courses are defined within narrow parameters. Teachers, students and parents rigidly believe that the biology, chemistry and physics sequence parallels appropriate mathematics courses and that this is the proper preparation for college. The content of these courses has become highly refined. To modify the courses to include technologic content or to deal with science-society issues would necessitate reducing or deleting science information accepted as important.

Several levels of "screening" exist which selectively encourage or discourage various student types. The screening occurs in various ways. Any single individual is subjected to the process several times. Thus, students receive many signals concerning their respective capability and worth. Students who view themselves as college preparatory will elect to take the narrowly defined courses in the college-preparation track. (It is not clear how a course becomes so labeled.) In the process of going through the "appropriate" courses the student receives feedback relative to his/her potential success. For example, the most common sequence of natural science courses is biology - chemistry - physics (RTI 56). When these courses are taught in an elitist fashion the student is confronted with a sequence representing increasing abstraction.

Students are simultaneously screened for science careers through the mathematics curricula. Mathematics, which is supposedly essential to the sciences, has even greater problems with respect to elitism and sequencing (CSSE 13:27). Students are faced with little flexibility in course scheduling or special interest courses. Nevertheless, status-oriented students do take mathematics and science (CSSE 15:26).

An additional element influencing the course selection of the future leader is found in the school counseling program. Counselors tend to "track" high ability students into courses believed to be college preparatory. There is a belief that such students must take the pure sciences (CSSE 12:25). "Filtering" frequently occurs in the process with high achievement students being tracked in one sequence and with "lower" achievement individuals being encouraged to take less rigorous courses. Counselors have even been reported to have steered students away from science to easier courses in order to preserve the students' grade point averages (CSSE 12:25, 15:29). Should some students with less than adequate skills in reading and other basics find their way into the more rigorous courses, they meet with difficulty because textbooks are abstract and written at a difficult reading level.

It is interesting to note that courses designed for the college-bound student are not a prime target of external pressure groups. Resources will be provided to these courses even under the most stringent budgetary restrictions. Furthermore, these courses have embodied in them the elements of "hard work" and "authoritarianism" (whether it be respect for the content or for the

teacher) found in the back-to-the-basics movement (CSSE 16:21; 16:6; 19:5). It is likely that the public will continue to support such courses even under the most difficult of financial conditions. The elitist perception of science is a self-fulfilling motion. The attitudes of students, parents and counselors are perpetuated by the standards employed in the course and the success ratio of students. In addition, the teachers' reliance on prepared curricular materials (textbooks and laboratory exercises) insures that the content will remain "pure", abstract and difficult. Thus, there are no forces which would put more stress on personal or societal relevance in these courses.

Problem 2: Courses which include basic knowledge and processes of technology and their relation to society are not widely available to the non-science-oriented "average" student.

As discussed above, traditional science courses reflect the philosophical view of science as a search for order. The content is rigorously guarded to insure that it fits this heritage (CSSE 12:9). Our review of the content of widely used science texts designed both for the science oriented and for the non-science oriented student, reveals that the entire student population is receiving content which generally has little direct generalizability outside of the laboratory. Hence, even the general student population is generally provided an elitist curriculum in the natural science courses required through grade 10, with little or no technology-related information (CSSE 18:81; 15:25-26; 12:17, 19; textbook reviews).

The curriculum systematically excludes technological aspects as indicated by the fact that references to technology are absent. Almost none of the topics we described in Phase I were represented in any of the widely used junior and senior high school texts identified by the RTI survey. This is true of the NSF-supported curricula as well as programs which were subsequently developed and which utilized the inquiry-oriented materials. Hence, general populations of students receive instruction which does not help them understand the technologies affecting society. Elitist science does not educate the young in the identification of technologically based problems and the problem-solving techniques necessary for developing solutions. Neither do students learn of the relation of science to technology. Military needs,

corporate growth, energy needs, etc., are not part of the curricula and therefore the public remains ignorant or is at best misinformed. Furthermore, parents, recognizing the characteristics of traditional science, may find it difficult to admit that what was part of their education may not have importance for most students in today's world.

Support for curricular changes is not forthcoming. Although less academic courses which reflect student interest do find their way into the curriculum, the content normally reflects the disciplines of science. Many popularized or "recreational" science courses (e.g., oceanography, edible plants, etc.) merely focus on transferring principles and content to everyday life in a faddish manner. There is no real attempt to apply scientific concepts to social situations or to understand technology. More frequently than not, the content is less rigorous than the traditional courses, and students, parents and teachers have little respect for such courses. It appears that college-prep students view these courses as irrelevant to their education. The same is true for technology-related courses. If resource reallocation is necessary because of budgetary problems or pressure for more time to be devoted to "basics", few people would really argue for the maintenance of these types of courses.

Problem 3: Non-academic students are sometimes provided courses which may contain elements of technologic knowledge and process. However, such courses are frequently taught at a low-cognitive level and are not issue-oriented.

Students classified as non-academic are frequently poor readers and lack computational skills. Texts for this population are written at oversimplistic levels. Complex issues are not treated in these texts. Although the screening processes described earlier apparently work well, not all students who end up in these courses are untalented; much has to do with attitudes.

The technology found in these courses tends to be low level and of a pre-vocational nature. This reflects the commonly held misconception that "slow students are good with their hands". Since the public and the schools are not as concerned about maintaining the course content integrity for these

students as they are for students in the more rigorous science courses, there is considerable flexibility in the curricula. If science-society issues are of interest, they can be incorporated without offending anyone.

Courses in this category are not likely to be affected by budget cuts or resource reallocation. In a real sense, such courses are part of the "Basics" to which attention is being given, but again these courses are for the non-college preparatory student.

### Summary

The curriculum is highly structured; considerable evidence exists which suggests that the textbook is or easily becomes the curriculum. The knowledge taught is ordered by the authors and merely accessed by the teacher who may or may not be able to modify the knowledge to fit the needs of the student (CSSE 12:4; CSSE 13:59; CSSE 19:7, OSU 114, RTI Highlights Report 16). A related phenomena is the belief of science and mathematics teachers that they must cover material (namely, that outlined in the textbook) (CSSE 15:6). Secondly, there appears to be a belief that the material must be covered in order to prepare the student for future courses (CSSE 16:21). Ironically, the teachers of subsequent courses seldom believe that the material has ever been taught. This "preparation ethic" (CSSE 16:21; 12:16) apparently has little relation to the articulation of needs between elementary, junior and senior high schools (CSSE 14:28, 30, 31; 13:30; 12:17). A careful review of science textbooks clearly illustrates the lack of careful consideration of technology. While an occasional photograph of mankind's technologic prowess or a seemingly out-of-place reference to some industrial accomplishment can be found in almost every text, there is no systematic treatment of the science-technology-society interaction.

### Program Implementation

#### Program Visibility

It is reasonably well established that the textbook is essentially the curriculum for the instruction of science. Therefore, it is fairly safe to infer the type of education being presented to students, knowing the textbooks that are in use. To reiterate, a review of the most commonly used textbook

shows that science-technology-society issues are not integrated into the widely used material.

A selection of texts and supplementary materials which do stress STS topics is available. However, Weiss (RTI B33) shows that those curricula which were developed for the purpose of providing students a basic understanding of the STS issues, are not used. In fact, they are virtually unknown among teachers. Teachers in grades 7-12 report "having seen" and "having used" a fictitious curriculum (that was included in the study as a validity check) more than they report having seen or used one of the leading technology-oriented curricula! There may be many other reasons to explain this lack of use, but the fact that teachers do not even know the materials exist is certainly a partial explanation (RTI B38-B39). However, it is not clear why those teachers who not only are aware of the materials but have actually taught them subsequently return to more traditional curricula.

### Teachers

Teachers face many problems which mitigate against use of STS materials. Teachers apparently have greater faith in the advice and information supplied by their peers and local inservice programs than in any other source (RTI B118). These data may be misleading in that responses may be reflecting day-to-day problems rather than larger science education issues. Yet it appears that inservice programs tend to ignore the needs of the beginning teacher (OSU 73). The Ohio State document further reports that generally "inservice education, other than that promoted through NSF programs, does not appear to have been a major concern of science educators and researchers," (OSU 80). Updates on content and curricula remain as needs.

Teaching assignments often do not match the training (OSU 90). The junior high schools perhaps suffer the greatest in that individuals who have a minimum of preparation (minors in a discipline) frequently receive appointments to teach in their minors, or in subjects in which they received no college training (OSU 82). The ramifications of such misassignments are significant and go beyond the focus of this paper. However, one primary effect is that the teacher relies heavily upon the textbook (CSSE 13:59, 62, 63; 12:32; 15:6-7). Poorly prepared teachers cannot grasp opportunities to encourage the inquisitive student (OSU 118) or to relate the material to the general needs

of the student. This situation becomes even more acute when it is realized that not only are these teachers responsible for instructing students in the minimal competencies, they also are involved in the establishment of the minimal proficiencies.

The problem of teacher education is further exacerbated by the total lack of experience with technologic education. The importance of such experience is described in the 1971 AAAS document, Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics, which clearly articulated two major needs:

- a. teachers need knowledge and experience to illustrate the cultural significance of science, to relate science and mathematics through technology to social conditions, and to apply such knowledge to studying societal problems; and,
- b. teachers need to attain broad minimum competencies in technology and technological problem solving skills.

The AAAS document recognized that the student will need to learn such knowledges to be able to function in a future greatly influenced by technology. Although the three research reports do allude to occasional treatment by teachers of societal issues such as environmental quality (CSSE 12:43; 16:33; 17:11), population (CSSE 12:77), natural resources (CSSE 12:31), human engineering (CSSE 16:33; 12:27), and energy (CSSE 12:27); it is clear that there is no systematic inclusion of these issues in the curriculum.

#### Classroom Practices

There is a significant difference between the type of education in the elementary school and that which begins in the junior high school (discipline-oriented) (RTI Chap. 3). The senior high school further increases the emphasis on discipline-defined education and its analytical characteristics. An alternative way of viewing this transition is to view it as a shift in learning from the integrated manner with emphasis on interdisciplinary elements (science, as opposed to biology, earth science, chemistry and physics) to

learning which ignores the synthesis skills and qualities. This fragmentation is evidenced by the number of semester-long courses (RTI 65) in junior and senior high school.

The curriculum for grades 7-12 appears to reflect the structures of the disciplines as modeled in the universities. The difficulties of such a structure can be seen in the problems related to the acceptance of the curricula developed in the 60's which reinforced the centrality of the discipline. Several examples can be given of curricula that were developed to reflect the structure of the discipline rather than the needs of students and capabilities of the teacher. Certainly the problems related to the implementation efforts of S-APA, SCIS, PSSC, Chem Study, CBA and ESCP were at least in part related to the misfit of the curriculum to the classroom as known by teacher and student.

Class time, number of hours per week, has changed little over the past twenty years. The traditional 45-60 minute period has continued to be the main pattern of course presentation. Fewer than 10 percent of schools permit or encourage any variation in the instructional block (OSU 15). Elementary schools devote 19 minutes/day in grades K-3, and 35 minutes/day in grades 4-6 (RTI 50). The annual expenditure ranges from 11-14 cents per pupil (OSU 40). It is doubtful that any of these resources are devoted to technological education.

Teachers in junior and senior high school science appear to teach the same pattern that existed in the 1940's and 50's. The average load being between five and six classes per day (CSSE 18:20). There is no indication of class size; however, it can be estimated that the teacher is responsible for an average of 120 students per day.

While there may be some evidence that teachers are returning to the utilization of student-oriented strategies (OSU 85), the data are not clearly patterned. The lecture and discussion techniques are the most frequently used (RTI B60-B63) at all grade levels. In a sense, the limited use of equipment and supplies (RTI B84-B87) would suggest that students are doing more listening and discussing than doing "hands-on activities". It is of interest to note that teachers of grades 7-9 science do not generally feel the need for assistance in teaching lessons (RTI B112) and 50-55 percent feel no need of assistance for implementing instructional approaches which utilize inquiry or

hands-on strategies. This perception is also held by teachers of grades 10-12 science (RTI B115).

It is not clear as to who is responsible for career education. More often than not career decisions are a function of the built-in screening mechanism previously described and of parental and student stereotypes of science. If the scientific and technical manpower needs of the future are to be met, an increase in the quality and quantity of career opportunities information must be delivered to teachers. Teachers seem to take little responsibility for career advising. What information is provided to the student is frequently in the classical traditions of science and does not include aspects of technological or technical fields. Not all career opportunities require training as "Mr. Science"; the schools are unaware of what the job market is (CSSE 12:24-25).

#### Student Characteristics

The three research studies only indirectly provide profiles of student populations. The general characteristics of the students who would take the three types of courses described in the "Science Program Characteristics" section are somewhat vague but perhaps as specific as needed. The studies, however, do provide some insight into student attitudes and perceptions.

Student attitudes about science have been a frequent focus of study and are regularly reported in the literature. Usually the research is aimed at assessing the effects of specific techniques or courses. In the broader perspective these studies show that science is never rated high by students. For example, only 14 percent of 9-year-olds rank science as their favorite or second most favorite subject. Thirteen-year-olds give it a 29 percent vote and 26 percent of 17-year-olds rank it first or second (NAEP G01E01). The Ohio State study supports this analysis.

It appears that the student's perception of his/her ability is closely related to whether or not they take courses in science. Social, economic, and cultural factors definitely influence the student's perception of his/her ability (CSSE 15:39). Also, students tend to reflect parental biases and attitudes towards the science, which in turn influences the student's self-perception (CSSE 15:29-30). Student attitudes can become positive if success in courses occurs (CSSE 15:32-33). However, the effect of the screening

phenomena, as it relates to elitism, is to have failure more common than success. In fact, failure is expected.

The student's perception of his/her ability is also related to what some have labeled "fate control" (CSSE 15:37). If the student believes he/she has some control over his/her life, career expectations are considerably higher (CSSE 15:34-41). Inherent in the elements surrounding fate control is the sequential nature of the natural sciences and mathematics. Once out of step with the sequence, a student must have a sufficiently strong self-concept to do the necessary "remedial" work. Minorities, "late bloomers" and returning adult students are all faced with such remedial work and the likelihood of discouragement. These students will not have the opportunity to learn of science/society/technology issues. To categorize these types of students as non-academic is a social injustice.

#### Conclusion

Thus the student's education continues to reflect classical science, amoral, value-free, and pure-of-heart. The future leader, the future scientist and the future voter tend to receive an education that omits learning about the factors which will potentially determine the society in which they will live as adults. It is difficult to anticipate how these individuals will interact with technology of the future and/or make decisions relative to national defense, space programs, and R&D in general.

## RECOMMENDATIONS

The STS focus group has made recommendations for various audiences based on the problems identified in Section II. Hence audiences include: those working directly in and with schools; those concerned with teacher education; curriculum developers; and funding agencies and policy makers.

### Recommendations for School People

One of the groups of concern includes those people who are paid public employees involved in education at the state, county, and local level-- encompassing the chief state school officer and his staff, school superintendents and all school employees. For that group, we have the following suggestions.

- o School people should encourage textbook publishers to include STS material in their texts in all areas of science.
- o School people should encourage the development of special publications, films, etc., presenting specific STS situations such as auto safety, fiber optics in communication, and the connection between space exploration and the heart pacemaker.
- o School administrators at all levels should encourage teacher training institutions to include STS in their programs. They should also encourage the participation of teachers in in-service programs devoted to STS.
- o 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.
- o 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 be directed to all citizens of a technologically oriented society as general education.
- o Whether or not texts include STS material, teachers should be encouraged to include the teaching of STS when

it applies in the appropriate place in the courses they are teaching. For example, an explanation of radioactive decay might 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 the printed page.

- o 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 materials need to be eliminated.
- o 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.
- o School administrators should encourage and support teacher awareness conferences on STS curriculum and information regarding new technological developments. Recently the state school administrators of 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.
- o 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.
- o School officials at all levels should facilitate the integration of STS materials in curricula 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 could 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. One of the problems which emerges 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."

- o 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.
- o 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.

#### Recommendations for Teacher Education

Science-technology-society issues are not new on the teacher education scene. The National Science Foundation has long sponsored the development of curricula which deal with STS. Efforts have been made to implement the curricula through teacher education efforts. Technology education was and is a critical part of the in-service education of a small portion of teachers.

In 1971, the American Association for the Advancement of Science (AAAS) published Guidelines for Standards for the Education of Secondary School Teachers of Science and Mathematics. This association of scientists, the largest such group in the world, recognized the importance of teachers' being educated relating to STS. AAAS specifically stated, "Teachers need to attain broad minimum competencies in technology and technological problem solving skills."

Therefore, the credibility of STS as an educational component is established. However, the data show that teachers are unaware of the existence of related curricula (RTI, Table B.19). One might infer that teachers are also unaware of the STS issues even though the media has given high visibility to specific issues over the years. Hence:

Pre-service and in-service 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.

Since curriculum for Grades 7-12 appears to reflect the disciplines as modeled in the universities, and since teachers tend to teach as they were taught (OSU Table 6), 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 and establish the credibility of STS in public education. These courses should not be offered through the professional education (College or School of Education) but by the departments normally associated with arts, sciences, and engineering. Teacher education, as is any professional training effort, is the responsibility of the total institution. Therefore, the courses should be of a quality meriting "general education credit" which could be earned by any student completing the requirements.

Schools and Colleges of Education as well as in-service programs developed at the local level will include components of STS in their efforts. Whether this is accomplished through special courses, materials, or training sessions, the objective is to help teachers learn how to incorporate STS elements into existing programs and courses. (Although specialized courses are appropriate and need development, the focus here is the education of the teacher.) The teacher needs to know: (1) what are the most important components of STS which are relevant to the course, (2) what can be excised from the course without losing credibility, (3) what are the resources that are available, and (4) what is a reasonable expectation of student performance. With a knowledge of these four areas, the teacher would be able to screen and select textbooks for adoption.

Knowledge of these four areas would serve the pre-service and practicing teachers well. Such information is essential to the development of STS course-related instructional units; to the screening and selection of textbooks; and, for the development of curricula which reflect the needs of students at the local level.

It should be pointed out that the use of STS instructional activities in the discipline-centered courses (biology, chemistry, physics) would facilitate the student's ability to see direct applications of the course content. What might normally be viewed as esoteric information could be related to daily activities without a significant restructuring of the course. Students would be provided situations which would illustrate the direct effects of technology and the relationship of science to society. In such an environment the student would be learning the relationships of science-technology-society and of his/her responsibilities rather than being preached to about his/her duties.

Much needs to be done in teacher education programs to improve teacher awareness and abilities related to the inclusion and subsequent instruction of technologic education and science/technology/society issues. It would seem that many such "improvements" of pre and inservice programs do not involve wholesale curriculum revision or significant retraining. Rather, the integration of bits and pieces with on-going programs will not only initiate the awareness of and need for STS but will begin to provide the classroom teacher with the necessary knowledge and skill to work with students in an effective manner in the classroom.

The above recommendations and commentary are directed at the education of classroom teachers. School counselors comprise another important group needing information regarding technologic education specifically and STS issues in general. The data show that this population is very important in advising students as to courses to take and careers to explore. These professionals must be kept informed of new curricula and courses and the student population for which the programs are designed.

Not only are programmatic elements of importance to the counselor, the rationale of science education is a "basic" in any education must be clearly articulated. The perception of science as a course of study for a selected population or elite is no longer acceptable. Professional educators, whose responsibility it is to provide guidance and counsel to the future citizen, must be made aware of the critical importance inherent in technologic education as a basis for understanding the complex, technologically-based, world in which the student will work and live. Similarly, counselors must appreciate the strength of a science program in providing the student options

for career choices and personal development. A thorough analysis of the mechanisms by which to bring this information to the attention of counselors must be made and implemented as quickly as possible.

#### Recommendations for Curriculum Developers

In this section of the report the term curriculum developer is used to identify individuals or organizations involved in the creation, modification, or selection of materials that can be used in or support students' learning. The individuals or organizations in this category include a broad spectrum of titles and a wide variety of activities such as: a classroom teacher constructing learning modules for handicapped students; a curriculum team of classroom teachers modifying their middle school science program; a city-wide textbook adoption committee evaluating, according to a predetermined criteria, elementary science books; a state-wide curriculum committee developing a new course of study in marine biology; a nationally funded organization creating monies to support an earth science program; several authors collaborating on a new textbook series for a commercial publishing house; and a national science teachers' organization designing curriculum materials to address the energy problems of our country.

It is recommended by the Science, Technology and Society Focus Group of Project Synthesis that those individuals and/or organizations responsible for any type of curriculum development activity consider implementing into their work those recommended objectives and representative tasks of science education programs specified in Phase I of this report. The recommended objectives and representative tasks may be achieved by incorporating into local, state, or national curriculum development projects one or more of the following strategies:

1. Establish within the professional and lay community a philosophy that the teaching of topics in science, technology and society (STS) is an appropriate domain of science education; and the skills, knowledge and awareness of those objectives specified in Phase I of this report are essential for a well-rounded general education.

2. Evaluate existing courses of study and delete that material which is obsolete, or relevant only to the future scientist. 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.
3. Establish specific courses (full year, semester, mini-courses) that address contemporary STS topics. Data indicates that there are very few such courses and implementation of those that do exist has not been widespread.
4. Include as part of any textbook selection criteria a parameter dealing with STS. Studies indicate that the material contained within a textbook will, in most cases, dictate the instructional outcomes of the course.
5. Develop a wide range of materials to 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); and establish files of local field trips and community guest lecturers.

#### Recommendations for Funding Agencies and Policy-Makers

The purpose of this section is to suggest actions at the policy level, for those groups, agencies and foundations interested in stimulating technology education. It is extremely important to remember certain educational factors which serve as impediments to technology education and with which we must come to grips if technology education is to gain a foothold. As

discussed earlier, these factors include the academic preparation ethic, the training of science teachers almost exclusively in disciplinary science, overwhelming reliance on textbooks which are now generally devoid of technology, and generally shrinking budgets in schools, accompanied by vocal "back to the basics" proponents.

Technology education is in a state of infancy. There are few good technology materials, very few students enrolled in technology courses, little or no preparation for teachers to teach technology education, extremely little in-service activity regarding technology, and apparently little sentiment at the school level to change this situation. In fact, there is virtually no awareness of the existence of technology education at the local levels.

Given the situation in our schools and the state of infancy of technology education, we must accept the fact that increasing the amount of technology education is a long-term, "boot-strapping" process. The experience of NSF course development in the 1960's leads to the conclusion that simply pouring massive resources into materials development would be ill-advised at this time. What is needed instead is continued modest development in materials accompanied by activities on other fronts which will serve to develop a sound foundation for broadscale implementation sometime in the future. These activities can be classified into awareness activities, research activities, curriculum development activities, and leadership activities.

#### Awareness Activities

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 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. Essentially, these activities would be directed at "building a case" for technology education on a national scale. There is considerable evidence in our data sources that general rejection of innovative materials in the 1960's and 1970's was due in large part to the lack of teacher acceptance of the goals of the newer curricula. In technology education, we cannot afford to repeat that mistake.

Somehow teachers' perceptions of educational goals must be changed if there is to be any change in behaviors. We do not claim to have a complete plan for such an awareness campaign. However, some general strategies can be discussed. Because this is a long-term plan, it seems important to have a steady stream of low-profile information flowing into the system. Bi-weekly newsletters entitled something 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 there could even be complete classroom or individual activities included.

Because of the very large influence textbooks exert on content, it seems imperative to include their authors in this awareness campaign. Publications similar in intent, but much more sophisticated in nature, could be directed at showing how technological applications could be worked into traditional textual materials. It also seems cost effective to involve curriculum developers in "high prestige" invitational conferences where they could concentrate on technology topics and discuss possibilities for working them into the curriculum. Dollars spent in such conferences could conceivably have huge payoffs because textbooks appear to be the most influential factor in course content and a relatively limited number of text publishers and authors supply the bulk of the market. If the goal perceptions of those who produce texts can be changed even slightly, those changes may manifest themselves in the exposure of millions of children to some technology education.

Because of the dominance of textbooks in science education, their selection becomes an extremely important decision at the local level. For this reason, any activities which would result in the addition of technology-relevant criteria to that decision-making process could have a positive influence and should receive support at the policy level. For example, criteria for textbook selection could be developed in such a way that they would reflect science-technology-society concerns. Such criteria could be converted into checklists for use by states and locals 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.

### Research Activities

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.

Perhaps the most basic question is, "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 (see Phase I material) 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. Such a taxonomy would provide a checklist against which to compare developmental plans, course outlines, etc. and would provide a point of departure for discussing the field. 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?"

Following the development of such a taxonomy and compendium, the next important question involves the public level of understanding of various aspects of the science-technology-society interface. National surveys of knowledge relevant to this area would provide important information for future curriculum development.

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, and 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 role do district and state supervisors play, what is the nature of lay influence,

how do textbook salesmen fit into the process, etc. It is also important to know the kinds of factors which affect these decisions. For example, how do class size, number of teacher preparations per day, feedback from former students, textbook selection checklists, etc. influence the choice of curricula? Finally, we need to know what kinds of external voices have credibility in the eyes of the local decision-makers. Would they, for example, listen to professional organizations of scientists, teachers, or the college professors for whom they are preparing their students? Also needed is information regarding the extent to which these various decision-makers value knowledge about technological implications for individuals and society as a whole.

Another important school decision-making process on which we have little information is in the area of student course selection. 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 quite important. Factors needing investigation include: (1) the roles of teachers, parents, counselors, other students and written information in influencing such course selection; (2) course characteristics which are important to students and to those who influence students; and (3) student, teacher and community perceptions and valuing of technology-related courses and topics. It is important to know, for example, whether courses such as "The Man-Made World" are perceived as "dumb-bell physics", whether they are seen as useful for college-bound, non-technical students, or for those not going to college, etc. These questions about the decision-making process probably require some very specialized survey research combined with well-focused case studies.

There is also a need for a 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 their design or reporting. We do have information indicating that very little technology-related education occurs. However, we do not have information about the nature of that which does occur. For example, we know little of the preparedness of teachers in this area, of the way technology-related topics are handled in classrooms, of the nature of materials available, how accurately technology-related topics are handled, what sources of information have credibility, etc. We strongly

recommend that some attention be given to such questions in future research endeavors in science education.

### Curriculum Development Activities

There are two general avenues through which technology education can find its way to students in schools. One is by inclusion into existing curricula and courses, as discussed in the "Awareness" section. A second route is through courses specializing in technology education. Curriculum development activities should address both possibilities.

Materials developed for inclusion into existing courses appear most likely to succeed if their relevance to the specific content of those courses is explicitly evident and if traditional classroom procedures can be utilized as much as possible. For example, a module on genetic engineering would include information regarding connections between genetic theory (as traditionally discussed in biology texts) and possible new developments. It would also include some homework sheets (probably in the form of ditto masters), a few test questions a teacher might add to the unit exam, a list of terms with definitions, and clear instructions regarding how to fit the unit into existing biology courses.

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. We strongly recommend that no new developments be planned or funded without substantial planning and funding for broadscale dissemination of these materials.

### 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 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 would need to 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 education. Resources to be sought and organized would include: funding sources; groups, institutions, agencies, and individuals who support technology education; and materials and techniques which have been developed to aid technology education.