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ABSTRACT

Summarizes efforts of several representatives of the science education community to assess the current status of science education in the United States. The first section reports results of three surveys which were administered: (1) to gather current information about the nature and activities of the science education programs at 28 major universities; (2) to identify perceptions of problems facing science education by some of its practitioners; and (3) to collect suggestions from a sample of science educators for solving some of the current professional problems. A current status report is provided in a second section which resulted from an open forum with representatives from the 28 science education programs and from a synthesis of all major reports, studies, and analyses concerning science education as a profession in the last four years. A third section provides an analysis of the current crisis in science education from a philosophical perspective; and a fourth part deals with future steps, new directions, and needed actions in both policy and research in science education. (CS)

SCIENCE EDUCATION CENTER

The University of Iowa

June 1980

technical report 21

CRISIS IN SCIENCE EDUCATION

Robert E. Yager

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CRISIS IN SCIENCE EDUCATION

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CRISIS IN SCIENCE EDUCATION
Organization/Contents

Organization/Contents

Preface

In July of 1978, a small group of science educators attending an international conference in Israel were discussing the state of Science Education in America. It was agreed that such discussions should be expanded to include persons representing graduate programs nationally. During the fall of 1978 contacts were made and a series of written exchanges occurred which included contacts from the twenty-eight major programs for science education. A meeting of the group was planned the spring of 1979 at the time of the annual meeting of the National Association for Research in Science Teaching. The meeting included a single contact person from each of twenty-eight graduate programs as well as ex officio persons representing the National Science Foundation, the National Science Teachers Association, and the American Association for the Advancement of Science, and four year colleges with active science education programs.

Prior to the March 1979 meeting the National Science Foundation awarded a small contract to assess more carefully the status of science education in graduate centers. This contract provided an opportunity for a Steering Committee to form and to meet to accomplish a variety of tasks including preparation of: 1) initial drafts of this paper, 2) outlines for publications arising from the study, 3) questionnaires for a more complete assessment of science education nationally, 4) plans for presentations concerning the current crisis in science education at a variety of professional meetings, and 5) proposals for next-step actions.

The Steering Committee first met in May of 1979 for preparing an initial draft. It was circulated and rewritten before the first "public" draft was circulated to all who participated in the open forum in Atlanta. The paper was rewritten during the fall of 1979 with input from the science education community and the National Science Foundation. This paper then is an attempt at understanding the current crisis in science education at the beginning of the 1980 decade with major input from many active researchers in science education. It will be distributed widely to all contributing authors and to leaders of such professional groups, as the National Association for Research in Science Teaching, the Association for the Education of Teachers in Science, the National Science Teachers Association, the National Science Supervisors Association, School Science and Mathematics Association, the National Association of Biology Teachers, and the American Association of Physics Teachers. It is meant to supplement the NSF status study of graduate level science education which is being prepared as the final draft of this paper is released. During the next year the contributing authors expect this paper and the NSF status study to be used for discussion, debate, and planning. Hopefully the results represe[illegible] are but a first step in developing a new rationale for our discipl[illegible] and for solving many of the current problems which surround us.

Robert E. Yager

1. REAPPRAISING SCIENCE EDUCATION

1.1 Introduction

James Joseph Gallagher
Marjorie H. Gardner
Robert E. Yager

A series of events of the 1970's have created concern among science educators. The number of state science supervisors declined dramatically. City and county systems cut back severely on science supervisory personnel. Neither Stanford nor Harvard Universities replaced their eminent science educators when they retired. New York University let its science and mathematics doctoral program lie in limbo when its Director moved to Washington to lead the National Science Foundation Science Education Directorate. The Department of Science Education at Florida State University was abolished as such and many of the major curriculum development efforts were curtailed. The University of Maryland Science Teaching Center faculty declined from 12 to 7 members. These are just a few examples that demonstrate that a crisis is brewing as science education strength declines in public and private systems.

There is an urgency to the problem that confronts our discipline. Indeed, the description of the situation as one of crisis is accurate. However, it is important to remember that crisis also means a turning point. Actions can be taken to ameliorate the problem. Or, lack of action can result in further deterioration of our discipline. This paper is written with the belief that greater understanding of our problems - perhaps the reasons for them - can assist with revitalization of our discipline and our profession.

This reappraisal was begun by concerned science educators from institutions with major research centers, who are responsible for the preparation of significant numbers of science teachers and for doctoral programs which produce ninety-five percent of the new researchers and teacher educators. Science educators from major professional societies including the National Science Teachers Association, the National Association for Research in Science Teaching, the Association for the Education of Teachers in Science and the American Association for the Advancement of Science also participated. It is significant to note the unanimous view on the part of representatives of the twenty-eight science education programs and the professional societies that serious problems exist in science education. All were prompt in responding to the surveys, anxious to participate in an open forum, and willing to offer critiques and suggestions during the year-long effort this analysis has required.

1.2 Overview of Report

The frame of reference for the report and the organizational scheme for the separate sections is based on the following assumptions. Science education is the discipline concerned with the interface between science and society. In one sense, it provides the interacting link between the two. Science is represented by the various disciplines and includes the associated technologies. Society includes schools, teachers, students and the social interaction of all people. Changes in the interaction among science, technology, society, and education should result in new purposes for science education.

The report begins with an assessment of the current status of science education based on three separate surveys seeking to:

1) provide current information about the nature and activities of the science education programs at twenty-eight major universities;
2) identify perceptions of problems facing science education by some of its practitioners; and
3) collect suggestions from a sample of science educators for solving some of the current professional problems.

In addition, an open forum with representatives from the twenty-eight science education programs was held, recorded, and analyzed. Further, all major reports, studies, and analyses concerning science education as a profession published in the last four years were studied and synthesized. These sources and procedures resulted in the assessment of the current status reported in Part 2 of this report.

The third phase of this report is an analysis of the current crisis from a philosophical perspective. It arises from a prospective synthesis of current literature in science education and related disciplines, the analyses reported in Part Two, and the open forum. Such a perspective provides a context and a framework for analysis and reflection for ameliorating the crisis.

The fourth part of the report deals with future steps. It focuses on new directions and needed actions in both policy and research. The recommendations are proposed as a result of other recent attempts to change. The recommendations can be viewed as present day indicators for science education as a discipline.

1.3 Other Disciplines in Crisis

Although there has been great interest, support, and involvement on the part of the science education community, it is important to note that science education is not the only discipline in crisis as we enter the decade of the 1980's. To be sure, there is a confusion about the place and status of science education among the scholarly disciplines, but the problem is not unique to science education. The public is also questioning science, technology, economics, psychiatry, medicine, law and other specialities. All are being pressured to reestablish their legitimacy. At this point, some are responding with more fervor and more action than has the science education community.

All disciplines are being called upon to rethink their frameworks and the fabrics which comprise them. Society demands change because of social conditions; the disciplines themselves change providing still further and/or complementary demands. Such dynamics and such imperatives provide another major frame of reference for this report. The new decade is an appropriate time to ask continuing questions. What purposes are served by education in the sciences? What direction should guide those who teach science to youth and adults? How might science education be more responsive to current social conditions and current scientific thought?

2. ASSESSING THE CURRENT STATUS OF SCIENCE EDUCATION

2.1 Rationale for Status Surveys

David P. Butts
Rodger W. Bybee
James Joseph Gallagher
Robert E. Yager

Assessing the current status of science education is an essential and preliminary activity before new directions can be proposed and mechanisms developed for moving in such directions. All too little is known about the field, what is happening across the nation , what science educators are doing, how they think, and what new directions they perceive as desirable. For this report, the literature of the past five years has been surveyed. Demographic information that was collected five years ago as a part of the study conducted ancillary to the 1974 Guidelines for the Doctorate in Science Education (Butts, 1977) was available. The questions were: What changes have occurred during this five year period? What is the typical science education staff like? What are the perceptions of current problems in the field by active science educators? What do they see as desirable and feasible solutions to the problems? Such information was sought as the data base for the current study.

During the past year the U.S. Government Printing Office has released the results of three major studies of the status of science education in the schools of the nation (Helgeson, Blosser and Howe, 1978; Stake and Easley, 1978; Weiss, 1978). These studies represent major contributions to our understanding of the current status of science education at the elementary and secondary levels. However, these studies did not consider science education in terms of university departments and research efforts, nor did they analyze its unique features as a scholarly discipline.

Other studies have been conducted during the past few months which have synthesized information from the NSF status studies concerning school science, mathematics, and social science. Several professional groups have responded to invitations from the National Science Foundation for preparation of analyses of the status reports of science education for their respective organizations. These include the American Association for the Advancement of Science, American Association of School Administrators, Association for Supervision and Curriculum Development, National Science Teachers Association, National Congress of Parents and Teachers, National Council for the Social Studies, National Council for Teachers of Mathematics, National School Boards Association and National Research Council.

Two comprehensive synthesis studies also have received major NSF funding. These were Project Synthesis, (Harms, 1977) and the NCTM PRISM Project (Osborne, 1978). These studies provide significant information for this analysis/discussion, especially in the areas pertaining to the status of professional science education in K-12 schools.

One aim of this paper is to provide another focus for viewing the status of science education in the United States. It does this by studying and reporting the problems perceived by experienced university level science educators from institutions geographically distributed across the United States. Further, the science educators are employed at the twenty-eight major institutions for research and training in science education as a discipline as identified by Butts in 1974 (Butts, 1977).

2.2 Characteristics of Advanced Graduate Science Education Today

A student's experience in science is enriched by a well prepared teacher who has a thorough academic foundation and an equally clear understanding of what schools are expected to do for students and how science fits each society's expectations. Teachers are recognized as the major factor in influencing students' experiences with science. How teachers function in this role is the product of their academic preparation and of their continuing professional development. But what do we know about this development? In examining the academic and continuing professional development of teachers, two sources of data were tapped -- the context in which science education leaders are developed and the philosophical perspective of the faculty involved with preparing science education leaders. The science education leadership in this country is largely the product of the major graduate programs either directly through production of faculty for research centers or indirectly through preparation of the science education faculty for two and four year institutions.

To generate a current picture of the context in which science educators are prepared a questionnaire was devised and circulated to contacts from the twenty-eight universities mentioned earlier. The sample was expanded to include a small number of universities with Master's programs as the highest degree (see Appendices A and B for listing). The twenty-eight programs and institutions collectively are responsible for the preparation of nearly all the doctoral students and a significant number of the K-12 teachers. These institutional contacts were asked to locate needed information, to confer with other members of their respective units, and to consider some of the issues raised. (Appendix C includes the complete listing of science educators who are employed at the institutions involved in the assessment). A telephone interview was arranged to secure the information, thereby insuring clarity in terms of questions and responses as well as to assure a hundred percent response.

The information sought included names, teaching assignments, and research interests for staff. Data concerning student enrollment at all levels for 1974 and 1979 was requested including information pertaining to minorities, male-female ratios, and background education and experience. Other information concerning degree requirements, structure of programs, and changes during the past few years was requested as well. The institutional representatives were asked to comment upon differences in needs and functions of graduate programs in 1979 in comparison of 1974 and 1970.

Tables One, Two, and Three illustrate how the findings of these interviews reflect what now is the context for science education leadership. In Table One, the focus is on institutional resources. The institutional resources which influence the program of professional development in science education are faculty, support for graduate assistants, and organizational location of the program. In Table Two, the characteristics of the graduate programs illustrate the diversity of programs that carry a common title. Graduate degrees in science education have tremendous variability in their requirements for preparation in a teaching field, in their pedagogy, and in their research. In Table Three, the current enrollments in graduate programs and the numbers who have graduated from undergraduate programs are summarized.

Based on the telephone survey (Butts and Yager, 1979) a typical science education program involved in the production of doctoral graduates in science education would have five faculty members, two with special interest in science teaching at the elementary/middle school level and three faculty members with interest in science teaching at the secondary level. These faculty members would be active in teaching in a small undergraduate program (eight elementary/middle school majors and twenty-one secondary science teaching majors) and a larger graduate program (thirty-nine masters students, five sixth year graduate students, and sixteen doctoral students). The research focus of the faculty would probably be of a professional/applied nature (teacher education or curriculum development) rather than in more basic areas (cognitive development). The faculty would most likely be an informal group within a department of curriculum studies. Decisions concerning directions of the science education program and control of its development would thus be the responsibility shared with colleagues who are not science educators.

In this context of preparation of doctoral graduates in science education, one in twelve students is from a non U.S. background, one

TABLE I

Instructional and Research Faculty/Staff
in Science Education for 1979
in University Departments, Centers, or Programs

	Number	Mean	S.D.	Range	Number of Institutions
Faculty	183	5	2.8	1-11	38
Staff					
Graduate Assistants (Institutions)	81	3.2	3.3	1-16	25
Graduate Assistants (Grants)	36	2.4	1.3	1-5	15
Organization					38
Department	7				
Center	5				
Program	16				
Informal Scheme	10				

TABLE II

Courses Required for Graduate Degrees in Science Education, 1979

Program	Average	Range	S.D.
Master's Degree (N=37)			
Semester Hours Total		(30-38)	
Quarter Hours Total		(45-60)	
--Required in Science	46%	(0-100%)	21.7
--Required in Science Education	27%	(0-53%)	12.5
--Required in History/Sociology/ Philosophy of Science	13%	(0-16%)	3.1
--Electives in Education or Science	14%	(0-41%)	11.8
Doctoral Degree (N=33)			
Minimum Semester Hours Total		(68-102)	
Minimum Quarter Hours Total		(90-170)	
--Required in Science	41%	(0-52%)	12.2
--Required in Science Education	24%	(0-44%)	10.6
--Required in Research Skills	14%	(7-27%)	5.8
--Required in History/Sociology/ Philosophy of Science	8%	(0.16%)	4.3
--Electives in Education or Science	13%	(0.19%)	6.2

TABLE III

Students Enrolled in Science Education Programs in Major Institutions, 1979

	Number of Students	Mean	S.D.	Range	Number of Institutior
Graduate Degrees Enrollment					
Doctoral	566	12.6	12.3	1-50	35
EDD	218	12.8	14.6	1-50	17
PHD	348	12.4	10.9	1-45	28
Specialists	67	4.8	5.7	1-21	14
Master's (MA, MEd, MS)	1110	20.2	22.2	1-100	55
--With Certification	366	14.6	19.4	1-84	25
--Without Certification	744	24.8	23.6	1-100	30
Undergraduate Seniors*					
Elementary/Middle	161	8.5	8.6	0-35	19
Secondary	784	21.2	13.5	0.53	37

* Number graduating in 1979

in three is a woman, and one in eight is from a racial minority. As they enter the graduate program, one in ten will have had elementary teaching experience, seven in ten will have secondary teaching experience, one in fifteen will have had college teaching experience, and about one in ten will have had supervisory experience or experience in health related fields.

For a masters degree the graduate programs consist of about 45 quarter hours (30 semester). Of this 38% will be courses in the teaching field and 25% in the teaching of science. At the doctoral level, a total of 130 quarter hours (100 semester) including master's work would reflect 38% in the teaching field, 25% in the teaching of science, and 13% in required research and statistics skills; the remainder would be in relevant electives.

2.2.1 Societal Attitudes

Changes in these centers for the development of science education leadership during the past few years reflect changing influences of both schools and society. Unfortunately the communciation among faculty and other staff members may neither be as effective nor as frequent as was desired by persons involved with the surveys. Consequently, the results of the survey are sketchy and, in some cases, inferential.

Many science education faculty members are becoming involved with general education. Many are active in such enterprises as environmental studies, community awareness activities, adult education, and the energy crisis. Some are developing new materials and new teaching strategies which meet current social demands. Some are intimately involved with the specific role and importance of science including career preparation for special populations, namely minorities, females, and the handicapped.

The course offerings, the research, and the service activities which characterize the largest centers of science education have changed. Science and society courses/research, involvement in health-related fields, activity in energy/environmental programs, involvement with the sociology of science, an awareness of crises in other disciplines and in society generally, and efforts to provide science for all citizens (including women, minorities, and the handicapped) are apparent concerns. They represent new directions in science education.

2.2.2 Rationale for Science Education

In a time of crisis, people are more willing to join in seeking solutions and new directions. In contracting science educators by questionnaires, in person, and by telephone general concern for the current crisis was expressed as well as willingness to become involved with corrective actions. Many reported major attempts at program restructuring, new activities, new ideas, and/or new philosophical statements. Most recognized the current time as one of crisis, and they realized the need for a common focus and leadership.

Where change is welcomed, programs seem to be more vigorous. New programs and activities tend to generate support and enthusiasm. Unfortunately, however, program activities and research productivity have diminished. As indicated initially, programs at major institutions that were active five and ten years ago have been abandoned or seriously cut. Nonetheless, based upon other correspondences with representatives from the twenty-eight largest institutions, science educators have demonstrated a willingness and a desire to be involved with efforts to ameliorate the current crisis.

2.2.3 Teacher Education

Since teacher education is a major teaching, service, and research commitment of the faculty at the twenty-eight centers, much information was gained from the telephone interviews concerning this aspect of program activity. The information presented here is qualitative but is included because of the directions and problems it suggests. The population of prospective science educators is declining. This includes both undergraduate and graduate enrollments. This reduction is caused by influences such as decline in overall college enrollment, more rigorous entrance and selection criteria, less family mobility caused by the tight economy and job market, and reduction of available financial support for graduate education. Teaching salaries in the secondary school (after five to ten years of experience) are significantly greater than those for beginning college faculty. This makes doctoral study aimed toward production of more college faculty less attractive. The reduced size of teacher education programs and graduate programs in science education is reflected also in a reduction of education faculty in colleges and universities. Such reductions force college faculty to broaden their instructional responsibilities and may explain a greater emphasis on practical and applied research. Such research has more immediate payoff than the basic research that is both more philosophical and longer term in its usefulness. It also reflects broader teaching and service activities.

Another influence on some teacher education programs is a shift in their position or priority in the college of university system. For a wide range of reasons control of science teacher preparation programs has steadily been moving from science education per se to other administrative units which have less commitment to science teaching per se, i.e., departments of curriculum and instruction. Policy and budget decisions thus tend to reflect priorities and pressures more general than science education.

When specific new activities/projects are tried at given institutions programs seem to be attracting more students and new research and teaching approaches are in evidence. This expansion also is seen in those programs which emphasize preparation for a broader range of professional goals than classroom teaching or conventional university science teacher education. This diversification of programs includes creative explorations of exciting and evergrowing technologies for instruction as well as materials and approaches for providing experiences in science for special populations or informal education (e.g. museums, television, etc.).

2.2.4 School Programs

The K-12 schools are vastly different in the late 1970's when compared with the decade of the 60's. Science is no longer an area of study associated with national needs. Science is not a popular subject; nor is it considered a basic in the way mathematics and reading are. School enrollments have declined and students are not enrolling in science as a necessary prerequisite for college. The result is a reversal in terms of the prestigious place once occupied by the science faculty and the science department in schools.

The decline in support for new curriculum projects and for in-service teacher preparation has resulted in a return to old course outlines and old teaching approaches. The NSF status studies suggest that school progams in science can be described in a single word - textbooks.

The present population of science teachers is older; many teachers have completed all the staff development activities that the school system will reward. Many who tried one of the new programs of the 60's are returning to traditional textbooks which also signal a decline in the use of the laboratory or the field. Few are calling for new approaches to school science while relatively few new and younger teachers are entering the profession. However, there is a concern for special education programs and for others which have been prescribed at national and/or state levels.

Summary. The survey of the major centers of science education revealed many problems for science education for the 80's. Among them are a decline in faculty members, doctoral students, support for graduate students, and general influence in schools through pre- and in-service teacher education. Schools are changing with respect to curricula, teaching approaches, and staff development needs. Science education programs are becoming more precise as to course requirements while they are becoming less autonomous within the university structure.

2.3 Problems as Perceived by Science Educators

As mentioned previously a mail survey of twenty-eight science educators at universities in the United States was conducted to collect information regarding perceptions of problem within the discipline. The science educators surveyed were associated with universities where most of the research is conducted and most of the doctrates are produced. Each science educator was asked to prepare a short description of his/her perception of the current problems in science education in the United States. Later the same participants were provided with all other science educators' responses; they were then asked to write a statement regarding possible solutions to the problems.

The participants presented their statements of problems and solutions in an open-ended narrative format. Each response was approximately one page in length. These responses were analyzed according to an emergent set of categories through an iterative process. The results of the survey on perceived problems are presented in Table IV and are discussed below. The results of the survey of proposed solutions to these problems have been included in Part IV of this report dealing with recommended actions for the future of our discipline. Results of the two surveys have been expanded into separate reports which have been published separately (Gallagher and Yager, 1980a; Gallagher and Yager, 1980b; Renner and Yager, 1980).

TABLE IV

RESPONSE OF 28 SCIENCE EDUCATORS REGARDING PROBLEMS FACING SCIENCE EDUCATION TODAY

I. Societal Attitudes toward Science	
A. General anti-science tenor of society	11
II. Rationale for Science Education	
A. Uncertainity about goals and objectives of science education	15
B. Lack of leadership of science education	8
C. Lack of theoretical base to guide theory and practice	6
III. Teacher Education in Science	
A. Poor quality science education programs	5
B. Lack of interactions between researchers and practitioners	4
C. Lack of valid inservice programs	4
D. Failure to help teachers understand the nature of science	3
E. Limited contact between university and precollege faculty	3
IV. School Programs in Science	
A. Declining enrollments in science courses	12
B. Poor teaching and counseling in science and mathematics	5
C. Lack of science programs for all students	4
D. Programs and movements that exclude science education	4
E. Changes in number, average age and quality of staff	4
F. Lack of achievements in science	3
G. Unionism and governmental control	2
V. Budgets for Science Education	
A. Diminishing budgetary reserves	9
B. Job shortages university science educators	5
C. Limited support for doctoral students	2
D. Program cutback	2
E. Federal budgeting schedule	1

Five major categories and twenty-one sub-categories were identified to organize the participants' statements of current problems facing science education as shown in Table IV. In Category 1, a societal attitude that constitutes a serious problem stated by eleven science educators was the perceived anti-science tenor in our present day society.

Problems related to the rationale for science education were frequently mentioned by the respondents. A professional identity crisis manifested itself in the numerous comments regarding the lack of a theoretical framework to guide research and practice in science education. Further concerns noted that there was uncertainity about the nature of the goals and objectives of science education and that the leadership in the profession was not providing adequate direction.

Teacher Education in science came under strong criticism as well. Poor quality of programs was a general comment made by five respondents. A more specific comment concerned our failure to help teachers comprehend the nature of science as part of their preparation. Two communication gaps were identified also: first, between university faculty and pre-college teachers and, second, between educational researchers and practitioners. Another problem area was the lack of inservice programs that addressed the professional growth needs of science teachers, including new curriculum models and experiences with science for special populations.

Problems Related to School Programs in Science were most frequently cited. Declining enrollments in science courses, declining achievements of students, insufficiency of programs to satisfy the range of student abilities, and programs that exclude science from the curriculum are some of the problems included in this category. Other problems of science programs included inept teachers, poor counseling, increasing average teacher age, reassignment of teachers to subjects outside their area of expertise, unionism, governmental control, and the shortage of science teachers.

Limitations on Budgets for Science Education were also mentioned as a problem for science education. A diminishing resource base, fewer needs for new faculty at the university level, limited support for doctoral students, program cutbacks, and the federal budgeting schedule were all identified as concerns.

Summary. It is apparent from Table IV that science educators in the twenty-eight centers have identified two kinds of problems of their profession for the 1980's. One kind of problem is on a philosophical level. It includes concern for the societal demands and expectations as well as lack of clarity regarding goals and objectives. These can also be seen in concerns for lack of leadership and a theoretical base. The other major kind of problem identified is that concerned with administrative matters including quality and organization of teacher education, declining enrollments, and inadequate finances. There seems to be some agreement that the philosophical problems were the more serious; in some ways the administrative problems were caused by failure to resolve some of the philosophical dilemmas.

2.4 Open Forum of Science Educators

The same group of twenty-eight science educators were invited to an open disucssion held during the Annual Meeting of the National Association for Research in Science Teaching in Atlanta, Georgia, on March 22, 1979. The purpose of the meeting was to discuss the problems facing science education today and to consider probable actions and possible solutions in a face-to-face setting.

The theme dominating the discussion of problems was the relationship between science education and society. Specific problems such as the need for new aims and goals, the need for leadership, the need for greater recognition of social problems, the need for an identity, and the need for financial support were all closely related to science education and its relationships to the larger society within which it is embedded. The disparity between the goals of science education (reflected in current science teaching practice) and the needs of society were represented clearly in statements such as:

"The most important problems facing mankind are not being considered at all in our schools." (Willard Jacobson)

"Society is extremely concerned about science. Society is extremely involved with science. The only problem is it doesn't happen to be the science we practice as a profession." (Herbert D. Thier)

"They are not buying the science we teach." (Jane Butler Kahle)

Summary. If the connection between society and science education were stronger, if we had a greater sense of our social purpose, then problems such as leadership, funding, and professional identity would be ameliorated.

2.5 Related Studies

In other studies involving people from most of the same centers, science educators have identified research priorities which provide additional evidence that the problems described earlier are indeed common to the profession (Helgeson, 1978; Yager, 1978; Butts, et al., 1978; Okey and Yeany, 1978). For example, two of the priorities listed in the top ten were aligned with: 1) definition and validation of goals for science instruction; and, 2) identification and development of teacher education strategies.

Major sections of the priorities paper (Yager, 1978) developed for the National Institute of Education included a definition of the unique features of science education and a delineation of a domain for the field as well as recommendations for needed research. Major discussions and debate were held at the 1977 annual meeting of the National Association for Research in Science Teaching concerning the definitions, the distinctions, and the priorities proposed. The priorities paper remains as a major attempt to develop a rationale and a definition of science education as a discipline.

A national survey of "Science Education Small and Large Institutions: '"Problems and Solutions" (McKenna, et al., 1979b) identified some of the same problems in science education as those discussed earlier, i.e. financial limitations, declining enrollments, and decreasing interest in science education programs. In another study the same investigators reported on a survey of problems and solutions in post-secondary science education (McKenna, et al., 1979a). Since these studies included science educators from both large and small institutions, the information is generalizable to several hundred more institutions and science educators. The results confirmed, in large measure, the problems cited earlier by the science educators from the twenty-eight largest science education centers.

Section Q of American Association for the Advancement of Science recently has prepared a statement for the AAAS Board of Directors which deals with "Perspectives in Science Education". This paper reflects contemporary concerns and identifies some needed actions which were used as an additional source of information for the new directions discussed in Part 4. (Watson, et al., 1979).

As we search for solutions to our problems in science education, some are looking to learning paradigms such as those of Ausubel and Piaget for a focus and for meaning (Novak, 1979; Marek and Renner, 1979). Others are rethinking the very nature of science education and offering new definitions and perspectives (Thier, 1971; Berkheimer and McCleod, 1979). These studies and these searches for a rallying point are again indicative of our current crisis. Synthesis of these efforts represent still inputs to the proposed new directions (Part 5).

Other works have attempted to review the history of science education to understand better the meaning of our present circumstances (Bybee, 1979a; Bybee, 1979b). Attempts to understand some of the recent reports of the National Assessment of Education Programs have implications for science education, especially as they pertain to the science, society, and the science education interface (Bybee, et al.

1979) and to the unique problems and perspectives of women and minorities in science and science education (Kahle, 1979). These considerations and analyses, as well as those previously mentioned, suggest the crisis condition, the need for corrective actions, and specific new directions.

Evidence was found also in other national studies indicating both a general crisis in science education and confirming many of the specific problems in the current discussions. One interpretation of the new evidence in the three National Science Foundations surveys of the status of science education (Helgeson, Blosser, and Howe, 1977; Stake and Easley, 1978; Weiss, 1978) is that science education is in a period of transition and reevaluation. The fact that the studies were done is an indication of the questioning and concern in science education. Another survey of both elementary and secondary science teachers in Michigan (Gallagher and Berkheimer, 1979) found that "confusion or uncertainty in goals and objectives", "limited budgets," and "limited time for science teaching" were top ranked problems.

Summary. The evidence suggests that the problems are pervasive throughout science education. Professors from doctoral granting institutions and classroom science teachers are feeling pressures and problems amounting to crisis. While each may have different pressures and problems, there is little doubt that the accumulated response of those in science education amounts to a statement of crisis.

2.6 An Interpretive Framework

The problem areas reported by science educators have been conceptualized, reported, and discussed within a specific frame of reference. This conceptualization of science education is an important assumption for the analysis of the present status and future direction of science education.

One of the important factors contributing to the problems in science education is the increasing disparity between the goals of science education and the present condition of science, society, and educational theory. This theme was certainly verified by the written and verbal comments of science educators. The diverse problems that were identified all seem to be symptoms of a larger problem, namely the increasing distance between the current goals of science education (as described by current practice) and the current needs of society. This problem requires a redirection of science education in order to produce a coherent response to the many problems.

At this point there is general agreement that the current problems in the discipline clearly suggest the need to change our aims and goals. The need to change is based on the many identified problems. In total, these problems are all indications that the old aims and goals no longer include the changes required of us. Unfortunately, we tend to identify the elements of science education that must subsequently be changed, i.e., teacher education, curriculum, degree programs; or some clearly identifiable referent of the interaction between science education and society, i.e., finances. While these changes are necessary, we must first define a clear direction for change which is a function of our history, our philosophy, and, very importantly, our relationship to society. Once we have identified such directions, our next task is to develop policies for research and practice in science education that will enhance the movement of the profession in these new directions.

3. A DISCIPLINE IN CRISIS: A NORMATIVE RATIONALE

3.1 Frames of Reference

Paul DeHart Hurd

Because the educational, societal, technological, scientific, economic, and cultural events of the 1970's and the early 1980's are not simple extensions of corresponding conditions of the 1960's, the result is confusion and mistrust in the public mind about what is worthwhile. Science education has not escaped challenges to its legitimacy as a discipline and as a vital part of the school program.

A reconceptualization of science education rests upon establishing the validity of its rationale and tenents in terms of the following:

- new concepts of the scientific enterprise resulting from the socialization of scientific research;
- shifts in science and culture resulting from the impact of science on social process and the developing science/technology/society paradigm, including a normative analysis of science and social indicators;
- perspectives on scientific enlightenment as science/technology influence the popular culture;
- new views on the nature and conditions of education for a changing society including alternative futures for science education;
- new knowledge related to the teaching and learning processes; theoretical advances in these fields;
- synthesis and a normative/theoretical analysis of research influencing science teaching including studies of intellectual

and social development, educational policy and goals, curriculum organization and instruction practices.

There is an acute need to study especially the mismatch between the discipline of science education and the present conditions of science, society, and educational theory. To date research in science education has not focused on this area of study.

3.2 The Need for a New Rationale

Much of the present crisis in science teaching results from a neglect of professional responsibilities. Little attention has been given to maintaining the health of our profession. Over the past quarter of a century science educators have pursued a laissez-faire attitude toward science teaching. Guiding forces have typically come from government agencies, research scientists, and professional scientific societies. There has been a modicum of rethinking, redefining, and much tinkering but little conscious activity to make professional scholarship (theory and research) reflect the changes taking place in science and society that influence educational practice. These accomplishments have little value for they are atheoretical and ahistorical. For this reason our ethical position has been dimmed. Consequently we cannot identify what we stand for as a profession, nor the direction we wish to move. We cannot make convincing responses to our critics. We, therefore, suffer an identity crisis and our professional worthiness is questioned. Medvitz and Watson recently discussed and analyzed this crisis as they studied the influence of professional associations in science education (Medvitz and Watson, 1978).

that they suggest a need for the reconstruction of science education as a discipline. Fundamental to this process is the establishing of a normative rationale (conceptual framework) of science teaching. The goal of a rationale is the achievement or order, coherence, and interpretation beyond that of mere appearance and common sense.

The issue of a normative rationale is that judgments can be made regarding progress and directions. Without a rationale, professional actions are random, unfocused, and lack conviction. In the absence of a normative position it is difficult to test hypotheses, or to synthesize and interpret the results of investigations, or to determine the validity of educational research and practice, or to identify significant patterns.

The need for a serious study of a rationale and goals of science teaching is long standing. More recently reports of both the NARST-NIE Commission on Research in Science Education (Yager, 1978) and the NARST Cooperative Study (Butts, et al., 1978) reaffirmed this need. The results of the surveys previously reported in Part Two substantiate the disarray and lack of coherence in the goal structure and normative basis of science teaching.

3.3 Developing a Rationale for Science Education

The development of a normative position provides a means for examining the status of science education, determining its ethical obligations, and ordering priorities. John Dewey's comment on educational stresses generated by social changes and their implications for a rationale are relevant: (Dewey, 1938)

> "All social movements involve conflicts which are reflected intellectually in controversies. It would not be a sign of health if such an important social interest as education were not also an arena of struggles, practical and theoretical. But for theory, at least for the theory that forms a philosophy of education, the practical conflicts, only set a problem. It is the business of an intelligent theory of education to ascertain the causes for the conflicts that exist and then, instead of taking one side or the other, to indicate a plan of operations proceeding from a level deeper and more inclusive than is represented by the practices and ideas of the contending parties."

"From a level deeper and more inclusive than is represented by the practices and ideas of the contending parties", as stated by Dewey, implies appropriate study and scholarship. Establishing a defensible rationale for science teaching is in itself a process of research. However, most of the philosophical discourse and modes of rationalism in science education have typically been entirely matters of debate rather than a consideration of conceptual notions derived from normative/theoretical analyses and logic. The determination of broad goals has been more an event than a process of philosophical study followed by cultural validation. Therefore, policies and issues have been hopelessly enmeshed in conflicts of interest, divergent pressures, biases, and competing value judgments. Goals are argued; they are not products of research, nor are canons for their validity established.

3.4 A Normative Base Leading to a Rationale

The AAAS Council in Houston, January, 1979, voted a new division titled Normative Science: Faith and Values. The NSF has for several years supported studies on Ethics and Values in Science and Technology

(EVIST). These and other programs on science/society interaction provide a means for identifying changing goals and issues in science education and for establishing changing goals and issues in science education and for establishing ethical priorities. What is basically encompassed in these programs is a recognition of a philosophical position regarding the place of science in society and the demand it makes for an education in the sciences.

Science education is a young discipline. In the fifty-year period of its existence, some progress has been made in establishing its unique position among the disciplines of either science or education. Its research methodologies have been adapted from and largely restricted to 19th Century concepts of science methodology useful for information gathering but providing limited insight into the deep human behaviors resulting from educational experiences. Whatever potential this accumulated information in science education may have is largely lost because of the lack of synthesis and interpretation. The absence of conceptual frameworks restrict the possibility that a creative synthesis will soon take place.

Some recent efforts to develop a synthesis of science education research include a meta-analysis technique. While meta-analysis is useful for more profoundly determining the extent of a relationship, it falls short of full promise, that of generating new hypotheses or a rationale for science education.

A current practice is to consider research in the context of a paradigm, a device used by Thomas Kuhn to identify the "structure of scientific revolutions" notably in the physical sciences. Paradigms are used in science education research to generate data from observations or measurements. But at this point the usefulness of paradigms is diminished for the lack of a rationale to give meaning to the data. H. Tristram Engelhardt, professor or philosophy, Georgetown University, describes the paradigm-rationale relation in the following way:

> "If one cannot supply a paradigm of paradigms, a set of transcendental conditions, one may have numerous limited areas of intersubjective agreement, but no common integrated reality." (Engelhardt, 1978)

Karl Popper's notion of a "theory of theories" is also relevant to this point.

This is the problem in science education; we have no story of stories and we therefore lack a universal agrument to sustain consensus on problems and issues. Without this consensus, expressed as a unifying theme, we cannot respond to our critics except at the level of triviality devoid of relevance. The problems and issues of science education will not be solved simply by more money, smaller classes, more doctoral candidates with bigger stipends, or other measures that simply represent extending common practices within an unspecified conceptual framework.

3.5 Limitations of Research in Science Education

The characteristic practice in science education research has been a constant effort to add new data to old problems in contrast to seeking new methods of dealing with old problems or perceiving new problems. One reason new problems are not recongized is a lack of historical perspective within the discipline. A second is the lack of any philosophical orientation. A third is the omission of the sociological and psychological dimensions of our discipline, and finally, a fourth is the absence of a normative rationale for science education; thus there is no way to identify next steps. James P. Shaver, writing in the Educational Researcher (January, 1979) states the issues this way:

> "...education research frequently fails as science because graduate training for educators all too often familiarizes them with methodology without immersing them in the philosophical underpinning, the basic orientation of science."

Dissertations are more a demonstration of skill in research techniques than a commitment to a significant problem.

To get insightful research on persistent problems of science teaching and to enlist new methodologies for doing so, it has become increasingly necessary for funding agencies to go outside the domain of science education. Perhaps this is the way it should be; a sizeable fraction of people who identify themselves as science educators are more concerned with applying educational research than doing it. Approximately a third of professional science educators have indicated they have never published more than one study and imply they do not expect to do more. They view their career as one of service (preparing student teachers, consulting in schools, conducting in-service programs) rather than of research contributing to the advancement of a professional discipline. For this reason they see normative/theoretical research, philosophy, and history of science education as lacking practical value.

The search for meaning and understanding in the teaching of science as it relates to a science/technology culture is of little concern in their professional lives. While only a third of science educators admit to this position, another third default their professional responsibilities in this direction. This situation in science teaching is more the crisis than are matters of money, enrollments, and teacher placement. What is to be the perspective of science education as a field of scholarship? What is its position in the life of the university?

3.6 Science Education as a Discipline

A characteristic of any discipline is the range of its domain, illustrated by the character of the literature it draws upon. Typically there is a unique body of philosophical (theoretical) and research literature that distinguishes one discipline from another. In addition, there is the literature of closely aligned and sometimes overlapping fields of knowledge that serve to enrich insight and stimulate new research within the central discipline. Edward O. Wilson speaks of the relationship between disciplines in terms of discipline and antidisciplines. (1977).

> "By today's standards a broad scholar can be defined as one who is a student of three subjects: his discipline, the lower antidiscipline, and the subject to which his speciality stands as antidiscipline."

A well-rounded science educator for example (to paraphrase Wilson) is deeply involved in the curriculum and practice of science teaching. He/she also understands the changing nature of the scientific enterprise, conditions of learning and instruction, and accepts the challenge to generate more valid and effective patterns of science teaching. Thus a science educator is required to know aspects of the history, philosophy, and sociology of science, to be acquainted with conditions of learning and cultural change, and to be able to synthesize this knowledge to advance education in the sciences.

These conditions tend to function at complementary levels of generalization (scientific enlightenment) and specialization (biology, chemistry, or physics teaching).

Seldom does one find citations to or recognition given to the "anti-sciences" when research problems in science education are reported. This has caused many scholars to look elsewhere for a rationale to give meaning to problems and issues in science education, for example to the sociology of science for goals and the context of curriculum, to bioethics for value perspectives, and to research scientists for the subject matter of science curriculums.

Of necessity modern scholarship, especially in educational fields, must rest upon interdisciplinary efforts, research networks, syntheses, and the interpenetration of knowledge and methodologies. The emergence of ethnographic methods of studying problems of science teaching is illustrative. Ethnographic techniques as Stephen Wilson points out (1977) are useful because they tap two important "hypotheses" about human behavior. One, the "naturalistic--ecological" perspective, regards human behavior as fundamentally influenced by the setting in which it occurs. This means that laboratory findings are not sufficient for generalizations about teaching and learning processes;

they cannot be approached unless we understand the framework shaping the subjects' thoughts, feelings, and actions (S. Wilson, 1977). Whether we accept or reject these hypotheses does not matter, but science educators must be more aware and definitive about the range of disciplines and research methodologies that represent the domain of science education.

3.7 The Ecology of Research in Science Teaching

Researchers in science education need a flexible, holistic methodology that allows them to describe the interaction of various configurations of goals, agents, resources, practices and events through which knowledge is acquired and utilized. This methodology should allow the researcher to perceive systematic relationships without forcing them in an overly simplistic fashion. Whatever the method utilized, it will be ineffective and meaningless without a normative rationale about science teaching to provide a basis on which to make inferences. It appears we have about reached the end, from the standpoint of productivity, of the natural-history phase of science education research. This phase is primarily concerned with information gathering, with fact accumulation, with correlation studies, and with over-reliance on statistics as methods. The justification of a research effort ought to rest as much on the worthiness of the problem as on the elegance of the technique. Quantification, a notion from 19th century science, has become a prejudice in science education research, not a principle of research. Quantification has the property to facilitate testing, but it all too often distorts the real world of relationship that makes research meaningful.

3.8 The Decline in University Supported Research

There is movement toward relocating educational research from universities to research centers or institutes, corporations, foundations, consortiums or research networks that may have only loose ties with universities. The reasons for this movement are:

- to work with mature, dedicated researchers (senior researchers) rather than to depend so much on the novice (a first effort by a doctoral student) for significant research;
- to have a more favorable environment for interdisciplinary research (university-based research is by tradition disciplinary);
- to get greater stability of management and staff for longitudinal studies;
- to better bridge the gap between theory and practice under real-world conditions (university-based research tends to over-emphasize contrived situations).

Something of the nature of this movement was described by Edward E.

David, Jr. in his AAAS presidential address (1979) commenting on the present range of industrial research in major companies:

> "Studies of educational methods and techniques are being carried out in many corporate laboratories. Both continuing and remedial education are included, as are knowledge and skills. There are a number of behavioral laboratories in industry, and a good deal of research on subjects in experimental psychology; for example, in visual and auditory perception and in motor skills."

3.9 What Are the Obligations of Science Education as a Discipline?

The major questions that need to be resolved in science education are:

- explicitly, what <u>is</u> its intellectual or scholarly context?
- what are its moral and ethical obligations to education in general?

There is also a need to evaluate the research that has been accumulated in science education to determine:

- what has been learned that is meaningful and useful in the real-world of science teaching?
- who is making use of what has been learned from the research in science education?

The crisis in science education lies in the pressures to establish the legitimacy of the discipline and to provide evidence of the worthiness and usefulness of the research produced.

4. TOWARD A NEW DIRECTION IN SCIENCE EDUCATION

4.1 The Basis for a New Direction

Paul DeHart Hurd
Jane Butler Kahle
John W. Renner
Robert E. Yager

An education for living in an age of science and technology as exemplified in the United States today and for the foreseeable future is a central goal of science teaching. The problems of energy production and use, the environmental degradation, the world food problem, and the environmental impact on health are but a few of the many problems we must resolve. Science/technology as a cultural force has an impact on a wide range of our economic, social, and political policies and decisions. This impact is both positive and negative. Clear recognition must be given to the role of science and technology in the resolution of the numerous science and technological related social problems of our age. This is a clear imperative for science education for the 1980's.

Within the past decade a combination of interacting scientific and technological social and cultural forces has emerged suggesting that new directions for the teaching of science are necessary. The scientific and social conditions which gave rise to the science curricula of the 1960's have changed and diminished the appropriateness of these programs for the teaching of science in the 1980's. The scientific community and science educators recognize the need to examine the current interactions among science, technology, and society and to project the implications of these interactions for the teaching of science in the decades to come (Bybee, et al., 1979).

Within the past years, the NSF status studies of K-12 science, the NARST/NIE priorities study, and the AAAS Section Q report as well as specific suggestions for solving our discipline problems from the contacts at the twenty-eight graduate centers for science education have been available for review and analysis. A review of all of these sources with emphasis upon the suggestions of the twenty-eight science educators provides a focus for positive actions to be considered at the earliest possible time. The recommendations are listed as a set of needed policy statements followed by a listing of the research needed in order to implement or alter the policy.

4.2 Policy and Research Recommendations

The recommendations which follow utilize the organization used previously in assessing the current status of science education and developing a philosophical perspective. They represent an attempt at synthesizing needed directions for science education as a discipline during the challenging decade of the 80's.

4.2.1 Societal

Policy

- Public education in the sciences is a responsibility of science educators, i.e. persons whose discipline deals with the study of the interface between science and society.
- Science education includes more than science teaching in schools.
- The teaching of science should be oriented toward the resolution of scientific, technological, and social problems.

. A rationale for science education should reflect the nature of science, the nature of society/culture, the expectations of education, the needs of human beings, and the way people learn.

Research

. There is a need to clarify the relationships among science, society, the rest of education and science education.

. There is a need to identify and validate the traits, skills, and attitudes of scientific and of technological literacy.

. The development of systems for synthesizing and interpreting research findings in science education for use by practioners (teachers and administrators) and for the general public is needed.

. A systematic and scholarly examination of science and social indicators to determine their implications for science teaching is needed.

. Research should be expanded to consider the ecology of science teaching.

. Specific information is needed concerning the role and importance of science for special populations, including females, minorities, and the handicapped.

. Research is needed on the present understanding and needs of science teachers related to science-related social problems.

. Research is needed on the use of non-school experiences for supporting school programs; i.e., museums, zoos, nature centers, television.

4.2.2 Rationale for Science Education

Policy

- Science education should be guided by a normative rationale and by associated research paradigms.
- Opportunities should be sought for carrying on interdisciplinary research projects with investigators in other social sciences.
- Further efforts are needed to establish cooperative research programs by individuals and among research centers.
- A major effort for research in science education should be to establish its usefulness for improving science teaching.
- Researchers engaged in carrying out dissertations or investigations should develop and report a synthesis of research findings relevant to the topic under study.

Research

- The rationale and goals of science education should be determined by a process of normative/theoretical research.
- A continuing system for identifying research needs in science education and for the development of promising methodologies for carrying out such research is needed.
- A systematic process for examining the research in cognate fields that may be useful in science teaching such as investigations on brain development, memory, artificial intelligence, and the sociology of science should be developed.
- Research on the psychology and sociology of science education is also needed.

. A systematic plan for the synthesis and interpretation of existing research on science education should be developed and followed.

. The development and testing of communication systems on research needs and the dissemination of research results on science education are needed.

. There is a need for research in the history and philosophy of science education since these areas form the background for a rationale and they are with few exceptions, not available in the science education literature.

. Research on structure of scientific knowledge is needed.

4.2.3 Teacher Education

Policy

. Teacher education programs should include experience with interpreting and utilizing educational research.

. An important feature of pre-service and in-service teacher education programs is a normative rationale for the teaching of science in a scientific/technological society.

. A continuing program of in-service education is a professional responsibility of all science teachers. A variety of in-service programs is essential to assure the professional growth of teachers.

. Efforts should be made to tie research more closely to teaching practices.

. Teacher education programs should emphasize the need for special attention to science for all with emphasis upon its importance and role for special populations (minorities, females, handicapped).

Research

- Studies are needed to determine the match between teacher education programs and the goals and objectives that guide teaching and learning practices. This study should examine the subject matter of both science and education courses.
- Studies should be conducted on the role and use of textbooks by science teachers.
- Studies are needed to determine how persons educated for science teaching may fit into other fields of employment such as allied health fields, environmental programs, energy use/policy, and museums.

4.2.4 School Programs

Policy

- The teaching of science in schools should have a focus on personal and societal problems and issues.
- The science curriculum should provide real-life situations for students to deal with value, ethical, and moral issues that are science based and conspicuous in our society/culture.
- A primary function of in-service education is to provide for a continuous program of curriculum improvement that reflects changing conditions in science, society, and educational research.
- The basic skills of communication essential for all students is a responsibility shared by science teachers.
- Teachers of science have a responsibility to provide students with opportunities to learn about careers in science and technology.

Research

- Basic subject matter for the science curriculum for various levels of school organization should be identified and validated.
- The intellectual skills required for rational decision making in a scientific/social context should be identified and validated and strategies for helping students acquire them should be investigated.
- Students focused on developing values and ethics as they relate to scientific/technological, and social problems and issues are needed.

4.2.5 Supporting Conditions

Policy

- Encourage and strengthen the position of science coordinator in schools.
- Funding must be adequate to sustain research in science teaching and to provide for its implementation in school settings.
- A closer tie between school and university faculties is imperative.
- Require the assignment of qualified teachers to science classrooms.

Research

- The development of research methodologies that involve teachers as associates in research on science teaching should be strengthened.

4.3 Beyond the Crisis

There is no easy solution to the current problems in science education. To be sure an important step is the recognition of a crisis --its causes, its magnitude, its complexities, its seriousness, its meaning. Such recognition and such understanding can do much in moving the profession beyond the current situation.

In order to take advantage of the opportunity afforded by the crisis, we need to propose, to debate, and to use definitions of the domain for science education; such definitions should not be voted upon, agreed upon, or compromised. The definitions should be derived from our history and the contemporary situation in science, society, and education. They can, nonetheless, provide intellectual and scholarly contexts for actions within our field. We need to analyze, synthesize and, finally, utilize what we know about science teaching. This needs to be separated from the dogma which so often engulfs and governs what we do. We need to capitalize upon our successes with meeting past crises; since each age brings new challenges and new problems, we must look upon the current crisis as opportunity.

At this time of crisis in science education we need to show uncommon ability in viewing the common problems. First, we need to step above our own personal orientations, projects, and problems and focus on the generalized needs of science education. Science educators must be aware of the philosophy, history, and sociology of science; be acquainted with cultural and societal forces which cause changes; be knowledgeable of the conditions which promote the findings of new knowledge; be able to utilize such knowledges for the advancement of the profession. Further, science educators need to discuss rationales, to identify new goals, to plan for the next vital steps for our discipline. We need massive response and action to a major crisis.

We selected the title "Crisis in Science Education" because it accurately characterizes our situation. There is indeed an urgency to the problems confronting our discipline. By every report, factual and intuitive, we are at another historical turning point. If nothing is done, if no changes are made, the field of science education no doubt will suffer further deterioration. However, there is the possibility of going beyond the crisis to a period of restoration in science education. This is our challenge for the future.

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APPENDIX A

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  Ernest Snyder
  William Tillery

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  Gerald Abegg
  Marion Harris
  Paul Marino

Carleton College
  Rodger W. Bybee

Columbia University
  Willard J. Jacobson

Cornell University
  Joseph D. Novak

Florida State University
  Lehman Barnes
  Ernest Burkman
  George Dawson
  Ronald Good
  Charles C. Matthews
  David Redfield
  Dorothy Schlitt
  William Snyder

Georgia State University
  Ted Colton
  Louis Gardner
  Mildred Graham
  Jack Hassard
  Edward C. Lucy
  Ashley G. Morgan
  Sydney P. Smith, Jr.

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- Dorothy L. Gable
- Albert W. Strickland
- James Weigand

Kansas State University
- Jerry G. Horn
- Robert James
- Harry McArnarney

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- Glenn D. Berkheimer
- Nettie Jean Enochs
- James Joseph Gallagher
- Martin Hetherington
- Richard J. McLeod
- Carl J. Naegele
- Edward L. Smith
- David F. Treagust

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New York University
- James V. Connor
- Judith S. Klein
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- Gerald Krockover
- Van Neie
- Floyd Nordland
- Samuel Postlethwait

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