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ABSTRACT

Using available data and analyses on the current situation in science and technology education, it was determined that science and technology education in the United States is lacking in two critical areas: recruitment and training of scientists and engineers, and nurturing a general scientific/technological literacy useful in all facets of daily life. Leading causes for these deficits are: too little classroom time in those subjects; inadequate curriculum materials which emphasize applications, interest, involvement, and problem-solving; and the decline in numbers of qualified science teachers and students preparing for the profession. Recommendations to remedy the problem include: requiring almost daily science and technology studies for everyone in kindergarten through grade 12; development of new curricular materials and wider use of some presently available materials; inservice education, preparation, and technical support through science specialists, regional centers, and contacts in science and industry; and recruiting and retaining more competent science teachers through increased professional satisfaction, participation in curriculum development, and additional pay. (Appendices include reports of working groups on: elementary school science; middle school science; biology, chemistry, physics, and engineering education; informal education; K-12 curriculum; integrating mathematics, science, and technology; technology in teaching; curriculum development; teacher preparation--K-8; teacher preparation--6-12; support for implementation/change; and the physically disabled.) (JM)

Report to
NSB Commission on Precollege Education
in
Mathematics, Science, and Technology

"A REVISED AND INTENSIFIED SCIENCE AND TECHNOLOGY CURRICULUM GRADES K-12 *URGENTLY NEEDED FOR OUR FUTURE*"

Recommendations of the Conference on Goals for Science and Technology Education Grades K-12

March 11-13, 1983
Washington, D.C.

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NSB COMMISSION ON PRECOLLEGE EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

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TABLE OF CONTENTS

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CONFERENCE ON GOALS FOR SCIENCE AND TECHNOLOGY EDUCATION, K-12
March 11-13, 1983, Washington, D.C.

Executive Summary

At the request of the NSB Commission on Precollege Education in Mathematics, Science and Technology the conference considered available data and analyses relating to the situation in science and technology education. The participants, broadly representative of the science and technology communities in education, research and application, reached the following conclusions and recommendations.

Science and technology in the United States is lacking in two critical areas:

a. The recruitment and training of enough competent scientists and engineers to maintain leadership in the technology so necessary to the nation's prosperity.

b. The nurturing in the general population of enough familiarity with science and technology facts and concepts and the facility with problem solving strategies needed so that every person can cope adequately with their personal lives, their work and their role as decision makers in our technological democracy.

Among the leading causes of the above problems are the following deficiencies in precollege science and technology education:

i. Too little classroom time in those subjects.

ii. Insufficient curricular materials that demonstrate the importance of science through applications, improve learning through the interest and involvement of the student, and cultivate the student's problem solving strategies.

iii. The decline in numbers of qualified science teachers and in students preparing for the profession. This is especially crucial in that rectifying items (i) and (ii) above will require more teachers with better training in teaching methods.

The recommended remedy for the problem (i) is to require science and technology studies for everyone almost daily from kindergarten through grade 11, approximately doubling the present exposure. Those students preparing for careers in science and technology would also be expected to take science courses in grade 12.

Rectifying the second deficiency requires the development of new curricular materials, and the wider use of some presently available materials, in which scientific methods, concepts and facts are applied by the students to problems and situations which they can perceive as relevant. In the past decade such curricula have been shown to be effective in improving basic skills, cognitive strategy and attitude towards science and mathematics. Further research in the teaching and learning of science and mathematics can optimize the effectiveness of the new materials and should be encouraged. These materials should emphasize phenomena in the local environment for grades K-6, personal health and biology in grades 7-8, and community wide problems with scientific and technological aspects in grades 9-11. Updating of the discipline centered courses for grades 10-12 and the partitioning of time between these disciplines each of these years is recommended.

The severe science teacher shortage should be urgently addressed in two ways. First, by quickly providing in-service education in the content and the methods appropriate to the curriculum described above and by revising pre-service college courses to convey the curriculum's teaching method as well as content. Further preparation and technical support for the teacher should be provided through science specialists, regional centers, and by establishing contacts with professionals in research and industry.

Second, by recruiting and retaining more competent science teachers. The following recommendations will help in this task: increased professional satisfaction from teaching better courses to interested students, (2) participation in curriculum development, and (3) additional pay justified by the need for more time for training and activities in curriculum development work, equipment maintenance and science fairs.

A strong, well planned support structure is needed to bring about the above improvements. Financial and planning support is required from federal, state, local and industrial sources. The importance of involving the research scientist in science education policy and development and the earlier successful experience of the National Science Foundation in science education improvement are compelling arguments for again channeling a major portion of support through that agency.

The establishment of a Joint Council on Science and Technology Education is proposed to formulate policy and monitor progress. A national center could be established under the Joint Council's direction to bring together the best people for policy discussions and research, to operate teacher institutes and to instruct the public.

Rapid implementation of the above recommendations is urgently needed. A beginning may be made in a few months using available funding, institutions and curricular materials. The program as a whole may take 10-20 years to implement.

The nation should recognize the importance and long range nature of science and technology education improvement by establishing and maintaining support structures of a permanent nature.

A more detailed list of the conference recommendations is in section IV.

I. Conference Origin and Procedure

The Commission on Precollege Education in Mathematics, Science and Technology was established by the National Science Board and the Director of the National Science Foundation in April, 1982. It was charged with the development of a national action plan to improve the effectiveness of the mathematics and science education in the nation's public schools. Having commissioned several studies, reviewed many reports, and held several hearings over the past year the Commission is now convening conferences to consider the evidence and formulate recommendations.

The Conference on Goals for Science and Technology Education, Grades K-12 was one of these, convened at the request of the Commission's Task Force on Education. Individuals representing science and engineering societies of research and education, school-science administrators and teachers, teacher educators and curriculum developers were invited to attend. Organizers and participants of the conference are listed in Appendix P. A collection of studies and position papers prepared in the last few years was distributed to the participants before and during the conference (see Bibliography, Appendix R). Thus the conferees were immediately able to discuss their views on the best solutions as described in section II. This led them to their own set of recommendations which are delineated in sections III and IV.

II. The Crisis in Science and Technology Education

As the health and prosperity of our society is derived more and more from technology, especially high technology, our future becomes increasingly dependent on the effectiveness of education in science and technology. Currently that education is failing us in two crucial aspects: (i) there is a developing shortage of the highly qualified scientists and especially engineers needed for today's research, industry and higher education, hindering our industries' productivity and competitiveness, and (ii) the scientific and technological literacy of the population is inadequate to cope with the tasks they must perform and the decisions they must make with respect to environment and human welfare concerns, as individuals and citizens in our technological world. While the former necessitates the training of more and better scientists, engineers and technicians, the latter requires a population sufficiently acquainted with scientific fact and technological applications and skilled in making decisions based on that knowledge.

Our elementary and secondary schools have a decisive role to play in rectifying the situation. They must encourage a larger number of youths to aspire to careers as scientists and engineers and better prepare themselves for college studies. The schools must prepare a much larger segment of the population to operate our technological tools, such as computers, at home and at work. In addition, the schools must provide the whole population with sufficient awareness of and insight into our technological world so that it can cope with the myriad ways in which technology affects private lives and the welfare of communities.

To meet the challenge the schools must overcome two obstacles: (i) the shortage of good science and mathematics teachers, and (ii) a curriculum which fails to inspire our brightest students to enter science and engineering careers and to provide the whole population with the needed level of knowledge and appreciation of things scientific and technological.

In the late 50's and 60's we faced a similar educational crisis dramatically emphasized by the flight of Sputnik. The nation responded with many new initiatives in curriculum development and teacher training, particularly through programs fostered by the National Science Foundation's Education Directorate. Public support for these programs waned for a variety of reasons including the decrease in Scholastic Achievement Tests and National Assessment of Educational Progress scores and other measures of science and mathematics ability. Ironically we have since learned in recent research (see Voss, Bredderman) that the new curricula led to better achievement than the traditional curricula. Further analysis (Jones) shows that the declines were minor or absent in the elementary grades, and also in junior high school biology and among those high school students intending to pursue scientific, technological or business courses in college. These are the areas for which most of the new curricula were designed and thus they were by no means the cause of the declines in scores. The reasons may have originated in societal changes and awarenesses which affected the students' home and school environment, but in any case were not due to the new curricula (Layman). In fact, national test scores are now beginning to improve and the newer curricula are playing a positive role in this change (Voss).

However the partial success of the curricular developments of the late 50's, 60's and early 70's by no means implies that we have adequate curricula for the present and future. The first wave of curriculum reform that began in the late 50's was directed at increasing comprehension of science concepts and less at motivation, awareness of relevance, and problem-solving strategies. The second wave beginning in the late 60's took advantage of what was learned earlier to correct many weaknesses and to provide material that brought more concrete experiences to mathematics and science learning and related it to the motivations of everyday life. This second wave was cut short in the mid 70's. Further experience and research since that time has indicated the need for further curricular improvements of importance. Much more is needed that illustrates the uses of science and technology and the power of scientific methods in tackling problems at all levels, personal, community and national. Motivation and process skills are not well enough represented in the available curricula. More material is needed which engages the student in complex, realistic problem solving activities and thus develops the higher level cognitive processes.

The critical shortage of teachers for mathematics and science in the schools will in the long run be alleviated by a curriculum which motivates and prepares students for science and technology-oriented careers. But in the short run, any intensification of mathematics and science education will make the shortage worse, while different emphases in curriculum content will widen the gap in teacher preparedness. Thus, of paramount importance are considerations which immediately attract more individuals into science teaching and offer more and better pre-service and in-service preparation.

Finally, the conference had to consider the climate of disarray in the support structure for education and its improvement. Negative public attitudes toward science and technology and toward our schools and their curriculum are reflected by lagging support at local, regional and national levels and by public pressures for change dictated by uninformed reactions. Hopefully more recent positive trends in the public perception of the role of technology and science and new information about how youths learn are preparing the way for major support of healthy new initiatives. How the conference dealt with all these issues is described in the next section.

III. The Point of View of the Conference

The Need

Views at the conference were in agreement with the major thrusts of the conclusions of the documents in the bibliography (see Appendix R). In particular it was agreed that the schools were not now providing enough science in the early years to make a sufficient number of students aware of interesting science and engineering careers. Equally important, the science that is taught is too rarely demonstrated to be relevant to the concerns of the students at their particular stage of development. Only a relative few are turned on by the natural curiosity that traditionally motivates scientific careers. Even fewer students have the opportunity to see the power of scientific investigation which also stimulates interest. Furthermore, it is the applications of science in every walk of life which are likely to motivate young people to consider careers in engineering. Such an early and motivating curriculum is also essential in providing the population at large with the general information concerning contemporary science and technology necessary to their own welfare and their role in the larger community. For them as well as for future scientists and engineers it is important that problem-solving and decision-making skills be developed so that they can (i) cope with the complexity of the technological aspects which affect their lives and (ii) participate in a democracy where the masses influence decisions concerning the use of technology.

There exist some good curricula in the separate science disciplines for those students who reach the last years of high school with suitable interest and preparedness. These courses, however, may need updating to take into account recent changes in the fields (in biology, for example, the role of genetic engineering), the effective use of microcomputers, and the sharpening of students' problem-solving abilities. However, the chief difficulty here is the shortage of competent teachers.

The Curriculum

Given the above considerations the conference came to the conclusion that science and technology should be taught in every year at an appropriate level and should be required for at least eleven years of schooling (see Appendix H). The required curriculum up to and including the 10th grade should use what is now available and develop further material that will (i) demonstrate the relevance of science and technology to many important aspects of the students' lives and their community and (ii) develop the higher cognitive strategies of problem solving and decision making. It was agreed that these latter process skills are as basic to our needs as those of computation and communication. A science curriculum oriented toward practical issues, however, is also an excellent way of fostering those traditional basic skills. The introduction of practical problems which require the collection and manipulation of data, the communication of results and ideas and the formulation and testing of solutions or improvements (i) improves the use and understanding of calculation and mathematical analysis, (ii) sharpens the student's ability to communicate verbally and in written form with precision, (iii) develops the higher process skills, (iv) imparts scientific concepts and facts as related to their application, (v) develops a respect for science and technology and more generally for quantitative observation and thinking, and (vi) stimulates an interest in many to enter scientific and engineering careers.

The conferees were impressed by recent research in cognitive process and science teaching which has shown that curricular materials and teaching strategies that are application and activity-oriented and involve realistic problem solving produce improved results in learning content and process and in developing positive attitudes (Voss). They were further impressed by the research which identifies specific strategies that further enhance concept and process learning (Greeno) and urge close collaboration of researchers with curriculum developers.

At an early age children are interested in the natural phenomena around them. In adolescence they are particularly concerned about themselves, their changing bodies and developing personalities. For these reasons it is advocated that in grades K-6 the emphasis be on a hands-on approach focusing on natural phenomena and problems in the child's familiar environment. Science should be taught daily in most of these grades. This implies about twice as much time devoted to science than at present (Hurd). In grades 7-8 there is an excellent opportunity for stressing various biological, chemical and physical aspects of oneself as a human being (see Appendix C) and personal problems in which science and technology play a role (clothing, drugs, weight and physical fitness, etc.). The above scientific activities will also present scope for the development of skills in the quantitative analysis of data and hence in the use of the computer.

Emerging from adolescence, youths become more concerned with their role in the community, how successful they will be in the world, and what the world is like for all. Hence in grades 9-11 it is recommended that the curriculum be structured around the interaction of science and technology with the whole society. Examples of the kinds of problems to be investigated that integrate knowledge from engineering, physics, biology, earth science, chemistry and applied mathematics are presented in Appendix I. The courses in these grades would be as intellectually demanding as the traditional courses. The quantitative and problem-solving aspects will be of much higher level than what is usually described as a "general science" course for non-science students.

At the 11th grade level many students are making decisions about their future careers and it is at this time that disciplinary courses to provide background for college study are needed. In the 11th grade it is recommended that such options be available for students as an alternative to the science, technology and community curriculum described above with more options available in the 12th grade. Of course other effective variations of options can be envisaged from 10th to 12th grade. In any case, the conference felt that more balance in the development of facility in the disciplines could be achieved if each discipline was taught for part of each year, for instance on the basis of three periods of biology and two each of chemistry and physics in grade 11 and three periods of physics or chemistry and two each of the other subjects in grade 12 according to the students' interest. Alternative schemes were a 3-2-2 balance over three years or a 3-1-1 over three years with only one year required of these students for the science, technology and community course. The offering of one semester elective courses in the science disciplines is another alternative to year long courses. The conference did not favor the omission of the proposed science-technology sequence in order that advanced-placement courses in the traditional sciences could be reached more rapidly.

Both the need for new materials and for about double the present science teaching staff would preclude the immediate implementation of the K-12 curriculum described above. It is estimated that full implementation would take about fifteen years. Many phases of the curriculum, however, could be implemented within a few years with available course materials and teachers, given immediate resources for teacher preparation. Much of the K-8 curriculum for a reduced total number of class hours and the conventional disciplinary courses in grades 10-12 can be implemented quickly. The science and technology course may be started with a one-year course and grow as materials, curricula and staff are developed.

Use of Technological Tools

The conference also considered the great advantages that can be brought into education through the use of new communication and computation technologies. Television and other audio-visual technologies can be used to stimulate thought, activities and problem solving, and to graphically illustrate worlds of place, size and complexity otherwise difficult to access. Calculators and computers can provide the computational and modeling power necessary for solving problems of real interest and can develop new systematic thought processes. Consequently the frequent use of broadcast, closed-circuit television and videotape and the early introduction of calculators and computers (before grade 6) is envisioned (see Appendix J). It is realized, however, that great care must be taken to avoid the overuse and misuse of communication and computation technologies in education that may arise because of the fascination of the media and our lack of experience about their effects. In particular the conference was anxious that these tools not be used to replace the self-checking learning that comes from interaction with reality, nor to replace the teacher in the bulk of situations where the teacher's understanding of student response is important. Television programs and computer software need to be developed specifically for the recommended curriculum.

Informal Education

Given the importance in the recommended curriculum attached to the interaction of science and technology with the real, natural and social world, the conferees believed that contacts with the community and opportunities for informal education should be fostered (see Appendix G). Parents and experts visiting the schools in various capacities, the students going out into the community to investigate and improve situations, to intern or observe career situations, and to participate in tours arranged by museums, Audubon societies, industries, etc. would all be valuable. The use of these informal opportunities are particularly important where school curricula and staffing are still deficient.

Teacher Preparation

The rate at which science teachers are leaving the profession (4% per year to non-teaching jobs) and the decreasing number of student-teachers preparing for and entering science teaching (64% drop from 1971-1980) is causing a growing shortage of qualified teachers for today's classrooms (as documented in the paper by J. A. Shymansky and B. G. Aldridge). This has resulted in a substantial proportion of high school science classes being taught by teachers not qualified to teach science (9% in 1981). The proportion of unqualified teachers is growing each year because half of the newly assigned science and math teachers (in 1981) fall into that category. The problem is nation-wide, only four state supervisors reporting an adequate supply of science teachers. The shortage of qualified science teachers may be worse in middle schools for which elementary certification is adequate in some states. Middle school teachers must also be skilled in nurturing the cognitive development of adolescents.

Thus the science curriculum already in place is being taught ineffectively in many cases because of the shortage of qualified teachers. The recommended increase in years of science courses for the whole population clearly exacerbates this situation. At the secondary level it implies a two-fold increase in science teachers. Further, it was recommended that there be a substantial number of science specialists at the elementary level to support the generalist teacher and also to teach classes in grades 4-6 (see Appendix L). In addition, many of the teachers already in the system will have to learn about the content and classroom methods appropriate to applications-oriented, problem-solving courses advocated by the conference. This clearly indicates that priority must be given to the recruitment, education and retention of science teachers.

To overcome the growing crisis in science teacher supply and qualification, the conference recommended a variety of forceful actions (see Appendices L and M). The first is the immediate availability of a large number of opportunities for in-service education. Qualified science teachers need courses which will update them in the use and effectiveness of the available curricula of the type recommended. The underqualified teacher needs such preparation and in addition needs courses in contemporary science and technology. Almost all teachers need to learn methods appropriate to teaching action-oriented and problem-solving material. Courses on the use of computers in science education are also important. In particular, the conferees recommended that teacher institutes be offered, structured to meet the above criteria, as soon as possible.

Ongoing support should also be provided to teachers of science. Various forms of support are described in Appendix N. Regional science teaching centers and hot lines to college scientists (see Appendix M) will help as well as more science specialists at district and state level. The support of the school principal is very important. He or she must be well informed of the needs of a science and technology education program.

Pre-service education is the key to the supply of teachers for the full curriculum described. Immediate attention is needed to the redesign of college instruction to train teachers in the methods as well as the content of the type of science instruction advocated. It was felt that not only the college course content but also the form of instruction must better match the application and investigation-oriented approach the prospective teachers are expected to use in the schools. The close cooperation of science departments with schools of education is needed to provide education students with appropriate science courses.

In addressing the need to attract and retain more competent people in science teaching, the conferees agreed that increasing salaries needs consideration. Differential salaries for science and mathematics teachers pose problems of equity and can run counter to present union principles such as seniority. The severity of these problems, however, may be obviated by relating extra pay to extra training, participation in curriculum development, maintenance of science equipment, the supervision of students in science fairs, and similar duties. Several states are now experimenting with some form of differential pay and the conference encouraged expansion of such programs to other states in this critical situation. It was felt, however, that pay is not the only incentive. The program advocated will increase professional satisfaction through the increased importance of science teaching, its larger role in the schools, more student involvement and interest, and teacher participation in curriculum development.

Support for Improvement

Given the difficulty of accomplishing the changes the conference recommended, the support structures needed to make it possible must be considered. More financial support for science and technology education will be needed at local, state and national levels. At the local level support for more, better paid science teachers and specialists is needed, for new equipment and new curricular materials, and for teacher preparation in the new curricula. The states can also support the improvement of college courses for teachers, regional science centers for teacher training and curriculum development. At the federal level the funding of teacher training institutes and developmental projects in curriculum, learning research and in effective dissemination approaches is desperately needed to revive the science education enterprise.

The mathematics, science and technology education programs of the National Science Foundation from the late 50's to the early 70's met the first challenge of this technological age. In retrospect we see that it met it effectively, producing important improvements in our science education. Some of the promising work being done in the mid 70's was left hanging in mid-air, with development incomplete or without an adequate dissemination. Some of these materials fit well with the requirements of the proposed curriculum and could be utilized quickly. The conference recommended that most of the funds now in the fiscal '83 National Science Foundation education budget be used for teacher training institutes designed to meet the criteria discussed above, and that much of the rest be used to complete and disseminate the best of the curricula developed earlier.

The National Science Foundation structure provides a unique and valuable interaction between scientists and science educators. In the past this was very fruitful in producing high level, relevant and scientifically accurate science and mathematics curricula. It is urged that this powerful synergy and the expertise previously assembled by the National Science Foundation education directorate be utilized again. Other federal agencies which support the general education enterprise must also emphasize the needs of youth and our society for better education in science and technology.

The program for change that has been presented is a complex and massive one and will require much planning and monitoring. The formation of a Joint Council of Science and Technology Education was proposed for this purpose. This council could bring together representatives of industry, education and science to plan the use of financial and human resources. In addition to and as a part of its policy formation activities, it was recommended that it create and operate a National Center for Science Education. In such a center resources and talent can be brought together to plan and stimulate the necessary research on science teaching and learning; and based on a synthesis of the results, develop and test curricular materials and foster improved programs of teacher training. It may operate a laboratory school and/or work with nearby schools (see Appendix N). It can serve as a model for regional centers throughout the nation.

Finally, the conference believed strongly that improvement of education, all education, should be a long term national priority. Although it is hoped that substantial improvement can be made in 5-15 years, this does not imply that national attention and support can be decreased drastically after that time. That was a mistake of the post-Sputnik era which can be repeated only at our peril as a leading and prosperous nation. Not only do education research, development and classroom trials take several cycles of work to produce a near-maximum result, but changing social and technological circumstances will require continual adaptation. There should be a continuing resolve to provide substantial and permanent support for that great individual and national resource, education.

IV. Recommendations

In the preceding section the conference's recommendations have been presented in the context of its view of the situation and its rationale for improvement. The reports of the conference working groups in Appendices A-O contain more detailed discussions of aspects of the problem, more specifics of the recommendations and many explanatory examples and comments. The groups met separately during the conference. Consequently their reports may conflict with each other in minor detail, and they contain a few recommendations which the conference as a whole did not have time to consider. In this section the main conclusions and recommendations of the conference are concisely listed for the convenience of the reader.

-The Task-

- Education in science and technology is of great importance to every individual who must cope with our technological world and take part in our democratic process.
- Education in science and technology is necessary to produce the scientists and engineers needed.
- Science and technology education is a "basic" for the modern world.
- There is an urgent need to extend and improve science and technology education in grades K to 12.

-The Proposed Curriculum-

- Science and technology education daily in every pre-college year.
- Emphasis in grades K-6 on phenomena in the natural environment, collecting and processing data, a balanced physical and biological science program.
- Emphasis in grades 7-8 on biological, chemical and physical aspects related to the personal needs of adolescents and to development of quantitative analysis skills.
- Emphasis in grades 9-11 on the application of science and technology to the improvement of the community, local and national.
- Options in grades 11-12 for discipline-oriented career preparation courses, preferably with several disciplines taken each year rather than one science subject each year.
- Grades K-11 program be an integration of science and technology and practical mathematics.
- Introduction of concepts of technology, such as feedback, alongside concepts of science.
- Curriculum be organized around problem-solving skills, real-life issues, and personal and community decision making.
- Research in teaching and learning be applied to identify desirable characteristics of curricular materials and teaching methods.
- Coverage of what is basic in contemporary science and engineering concepts and methods.
- Provision for interaction with the community and with informal education centers.
- Implementation of the above curriculum in stages as new material and qualified teachers become available.

-Use of Technological Tools-

- Television, computers and similar technology be used to extend, not replace, real experiences.
- Television productions be provided that stimulate thinking and doing, and present phenomena not easily accessed in the school environment.
- Use of calculators and computers to process large amounts of data.
- Use of computers to model realistic situations.
- Development of logical procedures through programming structures.
- Development of computer software specific to curricular needs.

-Measuring Achievement-

- Formulation of standards for achievement in basic problem-solving skills and in science content.
- Evaluation of achievement by testing process skills and integrated knowledge as well as facts and concepts.

-Teacher Recruitment and Education-

- Science teachers be qualified as well as certified.
- Rapid design and implementation of teacher institutes and in-service courses to update and qualify teachers, with special emphasis on methods of teaching integrated

science and technology and problem solving to the various age groups.

- Teacher institutes on content be started now for the presently unqualified science teacher.
- Development and implementation of pre-service courses which focus on instructional methods relevant for the prescribed curriculum and on basic science content.
- Modeling in college education courses the teaching techniques expected to be used in the pre-college classrooms. This requires close collaboration of science and education departments.
- Middle school science teachers should be required to have specialist qualification.
- Preparation of elementary school specialist teachers in science for grades 4-6, and informing principals of the needs of a science and technology program.
- Encouragement of research on the training of teachers.
- Involvement of teachers in curriculum development locally, regionally and nationally.
- Consideration of differential pay for science teachers to attract scientifically and technically trained individuals to teaching.
- Differential pay be based on special training and special duties required for science teaching.

-Support Structure for Science and Technology Education-

- Increased financial and planning support from industrial, local, state and federal sources.
- A systems-oriented approach for overcoming the many obstacles to improved science and technology education.
- A leading role taken again by the National Science Foundation in science education improvement, building on the important connection it provides between the scientific and education communities and on its previous successful experience in education.
- Early allocation of funds in the National Science Foundation budget for education to appropriately designed teacher institutes and for completing, testing and implementing the best of its curricula that have been incompletely developed or implemented.
- Preparation and deployment of science specialist teachers to support the curriculum and classroom work of science teachers, to respond quickly to teacher needs for information, equipment, field trips, etc.
- Opening of regional science education centers for curriculum planning, development and dissemination, for teacher awareness and training, for evaluation and research, and for contact with the community through activities such as exhibitions and forums.
- Organization of a Joint Council on Science and Technology Education to recommend policy and monitor progress.
- Establishing a national center for science and technology education under the Joint Council which would bring together the best talent for varying periods of time to collect and analyze data on all aspects of the field, to conduct central research on science cognitive processes and learning, curriculum development and teacher training. It would have facilities for a science and technology museum, exhibitions, conferences and workshops. A laboratory school and/or collaboration with neighboring schools would enhance its development and testing of curriculum.
- National recognition that science and technology education is a long-term enterprise of great importance, requiring continuing support as well as urgent current action.

APPENDIX A

Report of the Working Group on Elementary School Science

Education in science is a basic in American elementary schools today. As science is the basic skill needed by students to explore and experience the natural and technological world, science education must start early and continue through a student's formal and informal education.

Tremendous strides have been made in elementary school science (K-8) teaching in the last two decades. Elementary school teachers recognize that to teach elementary school science effectively, there is a need for support, time and resources. Thus, the elementary group has developed a series of "absolutes" to meet the above needs. We believe these absolutes are the conditions necessary to bring about restoration and/or continued improvement in elementary science education through improved systems and teacher training to enhance the acquisition of basic skills by students.

Support Systems

1. Elementary teachers need TIME to teach science, to continue their education in science, and to prepare science lessons. A typical "elementary school day" should include science instruction based on a planned, stated program of studies.
2. Science does not exist outside of personal, societal and career goals and must be a part of decision-making processes at all of these levels.
3. Schools must involve adults, the community and the society in order for elementary school science teaching to be successful.
4. Elementary school principals need to be trained in the specific uses of support structures for the efficient use of time, the effective use of resources, and a conscious philosophy of teaching.
5. There must be support structures and personnel to assist teachers in teaching elementary science. All schools must provide specialists to assist teachers in the effective teaching of science, materials (of all kinds) essential for science teaching and support for preparing and using the materials.

Teacher Preparation

1. For elementary school science, there must be qualified, competent teachers who feel confident and therefore comfortable with science.
2. Teachers of science must have a sense of curiosity and a desire to continue learning. Teachers need to be learners.
3. There must be formal and informal ongoing staff development in science for elementary teachers.
4. Preparation for elementary school science requires more than science courses. It requires training in the methods for teaching science in the elementary school and in what is known about how children learn.
5. As emergency and ongoing funds become available for teacher training, a part of these funds should be explicitly set aside for elementary teacher education in science.

Teaching Basic Skills

1. Formal, systematic interaction with and observation of the real world are essential in elementary education. Elementary school science should provide much of this experience.
2. Basic skills in science include:
   - Recognizing problem situations
   - Developing procedures for addressing the problem
   - Recognizing and evaluating solutions to problems
   - Applying solutions
3. Schools must have standards for measuring the acquisition of basic skills in science, and teachers and students must be evaluated against these standards.
4. Evaluation of students must reflect a change from the learning of pure co .tent to the acquisition of basic skills in science (concept skills).
5. A good elementary science program should be a planned set of experiences representing a balance among the disciplines, a daily lesson, and (frequently) involvement in hands-on experiences.
6. The natural environment of the school campus should be used frequently as a laboratory setting. The use of local natural resources and educational resources (museums, aquaria, etc.) should be encouraged.
7. Students should be taught basic skills and how to apply them to both science investigations and other elementary study areas. Emphasis on collecting and processing data should allow the use of integrated skills, with objectives becoming more sophisticated at succeeding grade levels.
8. Teachers should be encouraged to capitalize on the high student interest in science ideas and materials by using science as the vehicle for teaching reading, language arts, communication skills and mathematics.
9. The use of adults in the school and community as resources can enrich the program and the people themselves can be enriched and informed through

their involvement with a program that reflects current science-related issues.

10. The quality of instruction depends largely on the school climate established by the building administrator and on the recognition of the teacher that teaching and learning science is important and can be interesting and satisfying.
11. Curriculum content should be based on what is known of children's interests, cognitive skills, etc. As the children l. n to read, use research skills, etc., the curriculum content and the skills used should become more sophisticated.
12. Testing should measure the skills and/or content that is being taught. For example, if the lesson or lessons focus on the skill of classifying, then test items should evaluate the child's ability to classify.

13

APPENDIX B

Report of the Working Group on Middle School (Junior High) Grades 6-8

Status

Middle school teachers and students often feel an identity problem. Teachers must fluctuate between a nurturing elementary teacher and a content focusing high school instructor. State certification requirements across the nation reflect this problem with some states requiring an elementary certificate while others require a secondary certificate for this level. Middle schools frequently absorb teachers displaced because of declining enrollments. These people are often untrained to work effectively with young adolescents or in the content areas which they are asked to teach.

The student population manifests a wide range of maturity and developmental levels both physically and cognitively. It is not uncommon to find students functioning at the concrete, transitional or formal operational level in the same classroom. It should also be noted that the developmental level at which a particular student operates may vary depending on the assigned task. Personal awareness and questions about their surroundings often dominate students' thoughts and energies during these years.

Curriculum Recommendations

The middle school experience should enhance and further develop the basic skills of science introduced at the elementary school level. Academic growth and challenge should be developed through the exploration and application of scientific concepts.

A. Concrete experiences should be used to build on and further develop the basic skills of science introduced in the elementary grades.

B. Though the emphasis of the program should focus on concrete experiences, problem solving and logical reasoning experiences should be interwoven so that students can ask questions, manipulate variables, make generalizations and develop concepts.

C. The program should be exploratory in nature; an integrated or unified approach which covers earth, physical, life and health sciences during the year.

D. The program should interact with other disciplines. (Acid rain or nuclear power—science and social studies; data collecting or graphing—science and math.)

E. Career education in the areas of science and technology should be brought forth where appropriate.

F. Materials and topics should be developed in a differentiated manner in order to provide for the various ability levels within the grade.

G. The program should reflect decision making, so that students can evaluate personal and societal implications in regard to science and technology.

H. The use of new technology (microcomputers/calculators/cable television) should be integrated in the program so that students can experience their usefulness and evaluate the potential of these tools.

I. Use of local resources (museums, scientists, specialists) should be encouraged in order to extend the learning experience beyond the school walls and hours.

Professional Recommendations

A. Teachers must be certified in the areas of science for this level.

B. Opportunities are necessary for formal and informal ongoing staff development/training in the areas of science curriculum, adolescent behavior, classroom management and new technologies.

C. Support structures to assist teachers with state of the art ideas, resources or material.

APPENDIX C

Report of the Working Group on Biology Education

Current school offerings in the biological sciences

Biology topics are part of the elementary school science curriculum from kindergarten through grade six. In the middle/junior high schools (grades 6,7,8 or 7,8,9) biology may be concentrated in a one-year life science course, or be included as a part of general science in a three-year program. In the senior high school, biology is a year-long course typically taught in grade 10, and enrolls approximately 75 percent of all students. Advanced biology is taught in many schools in grades 11 or 12. The course may be general biology of the advanced placement type, or more specialized courses in anatomy and physiology, marine biology, ecology or environmental science.

The present condition of biology education

Since biology is a part of elementary science it suffers the same neglect as all science in elementary schools. However, elementary school teachers are more likely to stress biology than the physical sciences whenever science is taught. The teaching emphasis at all grade levels is largely upon learning the names of plants and animals, their structural parts and the function of each. The student complaint is that "there are too many names and terms to learn." Certified teachers of biology are not in short supply. The teacher problems are those of misassignment within the schools, tenure and hiring practices, and the educational qualifications of teachers. Results from the national assessments of science and standard tests indicate little decline in student knowledge of biology over the past dozen years. The primary need for the revitalization of biology education is perceived to be a conceptual framework that is more in harmony with understanding oneself and which is supportive of the national and global welfare.

Recommendations to the NSB Commission

The biology group recommends that the educuational context of the biological sciences be more sharply focused at different schooling levels. The curriculum in grades K-6 should emphasize a study of nature (plants, animals, humans—characteristics and diversity in the local environment) and biological phenomena (growth, reproduction, adaptation, behavior, and other topics). In the life sciences of the middle/junior high school grades, the emphasis should be upon understanding oneself as a human being. This will require a broadening of the present subject matter to include concepts from anthropology, behavioral sciences, cultural geography, human physiology, and other human sciences. General biology in the high school (grade 10) should emphasize biological knowledge in a social/ecological context. The focus should be on biological concepts as they relate to human well-being and the common good. The advanced or second level course in high school biology should be taught in the context of a discipline emphasizing its structure, its modes of inquiry, its theoretical underpinnings, and its career opportunities.

All students would be expected to enroll in the biological offerings in the elementary and middle/junior high schools and in the general biology course of the senior high school. These courses should be regarded as a part of essential learning for responsible citizenship. The second-level biology courses of the senior high school would be elective. These courses should be designed primarily for students who wish to test a career interest in the biological sciences, or qualify for advanced placement in college.

A substantial fraction of the course work in the middle/junior high school life science course and in the general biology (10th grade) course should be organized in terms of biologically based personal or social problems and issues such as health, nutrition, environmental management, and human adaptation. Whatever the problem or issue that is studied, students would be expected to deal with the situation by utilizing valid scientific information. The resolution of problems and issues in a biosocial context usually involves value or ethical considerations; these are not to be ignored in the teaching of biology.

At all grade levels there should be an emphasis upon biological ways of thought. Students would be expected to acquire skills in making careful observations, collecting and analyzing data, thinking logically and critically, and making quantitative and qualitative interpretations. Quantitative procedures would be those characteristic of the experimental or empirical sciences. Qualitative procedures include decision making in real-life situations and emphasize holistic or systemic patterns of thinking with considerations of probability and values or ethics. The two patterns of thinking may be identified as 1) procedures associated with the acquisition of reliable knowledge—biological inquiry, and 2) procedures associated with the utilization of knowledge in personal and social contexts—decision making.

Equally important throughout schooling is the need for students to identify sources of reliable information in biology that they may tap long after formal education has ended. First steps in this direction can come by making use of museums, parks, zoos, television programs, qualified people in business and industry, public library assignments, and from other informal sources of information in the teaching of biology.

Students will need an understanding of basic biological concepts and principles if they are to make responsible use of what they are learning. These concepts and principles should be acquired in terms of the human organism with extensions to other forms of life. Among the basic concepts in the biological sciences that have personal and societal dimensions are: genetics, nutrition, evolution, behavior, reproduction, structure/function, disease, diversity, integration of life systems, life cycles, and energetics. The student should also acquire an understanding of how bioengineering and biotechnology are used to modify or sustain natural systems in organisms.

Special efforts should be made in the teaching of biological sciences at all grade levels to develop bridges or connections between biology and other school subjects such as mathematics, social studies and the physical sciences.

APPENDIX D

Report of the Working Group on Chemistry Education

Two general types of pre-college chemistry instruction must be considered: (1) chemistry appropriate for all students, and (2) additional chemistry suitable for those intending study in areas requiring advanced preparation in this subject. All students, regardless of career goals, could follow a common chemistry syllabus (integrated or associated with other science areas), at least up to tenth grade. From this point we would recommend exploration of a two-track option—additional studies in chemistry for the general student (possibly integrated with physics), and more specialized chemistry study for those intending further work in this field. We recommend consideration of the Gardner/Yager 3-1-1 (or 3-2-2) sequencing of chemistry, biology, and physics study at the high school level for science-oriented students.

At all levels, the social and human relevance of chemistry should be emphasized. Problem-solving skills and application of scientific processes should be continually developed. Instruction should incorporate a proper selection and integration of topics from both descriptive chemistry and theoretical chemistry. Implications from recent research in cognitive psychology should be applied in establishing suitable criteria for this topic-sorting process.

Chemistry study should focus on observation and description of the behavior of common substances with the subsequent rationalization of what has been observed through development of simple models. Computer-based modelling of chemical systems (such as equilibrium systems, ideal and non-ideal gas behavior) should be explored, recognizing that such models should not be regarded as a substitute for direct student experience.

The number of topics covered in high school chemistry should be drastically reduced, with attention directed toward integration of remaining topics in two related ways: (1) integration of facts, concepts and principles within chemistry, and (2) integration of students' chemical knowledge with other sciences and with areas such as mathematics, technology, and the social sciences. High school chemistry must satisfy goals related to individual, societal and career-awareness concerns, rather than only addressing preparation for advanced study.

Barriers preventing implementation of new chemistry-teaching ideas include (1) The inherent resistance of textbook publishers to innovation or change. (2) A difference in the level of "respectability" associated by teachers with instruction in theoretically-oriented chemistry (high prestige) and applied (descriptive) chemistry (lower prestige). (3) The dynamics of the oft-cited principle that one tends to teach the way one was taught. (4) The general lack of suitable resource material to support the infusion of more applied, real-world examples into current courses.

Due to the effects of the "closed cycle" of university chemistry instruction necessarily influencing the nature of pre-college chemistry teaching, a comprehensive "systems" analysis and attack must be made in addressing the problem of high school (and pre-high school) chemistry teaching. The cycling time may be as much as 16 years. Thus, relatively long-term solutions must ultimately be sought.

This report at least partially reflects recent efforts within the American Chemical Society (ACS) and the National Science Teachers Association (NSTA) concerning pre-college chemistry teaching. This work includes many activities within ACS already reported to the Commission on Precollege Education (January 1983 meeting), deliberations currently in progress by the ACS Chemical Education Task Force, and NSTA's Report on the Desired State of High School Chemistry (1982).

APPENDIX E

Report of the Working Group on Physics Education

I. Why Should Precollege Students Study Physics?

An understanding of the basic principles of physics is a necessary foundation for most of the other sciences and for an understanding of many technological applications of science. Both the theoretical (testing hypotheses, deduction from observation, etc.) and the experimental techniques (measurement, error analysis, etc.) of physics have general application in science and technology. Even for those students who do not go on to major in science or engineering, physics provides important examples of how the physical world works and the kind of answers scientists can (and cannot) give to the important questions of life.

The basic coverage for a precollege student should include the traditional subject matter of physics: mechanics (especially force, motion, work, power, energy and the First Law of Thermodynamics), heat (including some kinetics of gases and the Second Law), electricity, magnetism, light and other electromagnetic radiation, atomic and nuclear structure and reactions. Precollege physics should be taught so as to demonstrate the general principles of seeking and knowing in science. The relevance of the understanding which physics provides to present and future problems and opportunities of our civilization should be constantly demonstrated and emphasized.

II. Use of Computers in the Physics Class

We welcome the use of computers in the physics classroom and laboratory if they are (1) used to increase the sophistication and satisfaction of problem solving; (2) taken advantage of in the laboratory for real time data collection, display, analysis, and storage; and/or (3) used to simulate real world situations that cannot easily be observed through direct demonstrations, laboratory experiments or field trips.

We are not excited about the use of computers as an expensive set of "flash cards" and believe that the replacement of direct labs or demonstration experiences by computer simulations is inconsistent with the evidence on how people learn from concrete *real world* experiences.

III. Structure of High School Physics Courses

We recommend that physics, chemistry, and biology each be taught over a three year period. A possible scheme would be the following, which gives number of class periods/week.

	biology	chemistry	physics
10th grade	3	2	2
11th grade	2	3	2
12th grade	2	2	3

Such a scheme would allow students (1) to develop their understanding of science over a longer period of time; (2) to provide opportunities for integrating the three sciences; and (3) to allow for a spiral approach to some of the more complex topics.

APPENDIX F

Report of the Working Group on Engineering (Technology) Education

WHAT WE ALWAYS WANTED TO DO

Get the general public to make informed decisions in technology area.
Develop confidence in the use of technological systems
(that technology can be a friendly aspect of life).
Prepare people for careers in technological industry.
Provide career information.
Provide a basis for personal decisions.
To help people overcome fear of change.

WHAT HAS CHANGED WHICH WILL HELP ACCOMPLISH THESE GOALS?

Technology which enables us to look at real problems
(using calculators and computers to do the "dirty math" enables us to use real data rather than canned problems).
Attitudes—specifically increased awareness of the environment.
Knowledge of how people learn.

WHAT ARE SOME THINGS WE HAD NOT EVEN DREAMT OF DOING?

Introduce technology concepts into other areas:
Trade-off, Feedback, Stability, Decision-making
Look at long term consequences of technological innovations.

WHAT IS IN THE WAY OF DOING WHAT WE WANT?

Reluctance to change.
Teacher perception of what is important.
Teacher shortage which results in additional numbers of teachers unprepared in the technology area.
Textbook publishers who need to "play it safe."
Teachers who teach the teachers.
Lack of understanding.
Standardized tests.

WHAT SHOULD WE TRY TO DO?

1. Gather and produce illustrative examples of ways to use the engineering concepts such as trade-off, feedback, and stability to help the public make informed decisions and prepare students for technology-based courses.
2. Encourage textbook publishers to include technology material in their texts in all areas of science and mathematics.
3. Encourage the development and use of special publications such as auto safety, fiber optics in communication, the connection between space exploration and the heart pacemaker.
4. Using knowledge gained from current publications of new technological developments, individual teachers and school systems should be encouraged to develop their own curriculum materials to fit the teaching of the new developments into their courses where appropriate.
5. A serious attempt should be made to introduce complete courses on science and technology into the school program for all students at the secondary level (specifically grade nine). These courses should not be limited to either the fast learners or the slow learners but should be directed at all citizens of a technologically-oriented society as part of the "basics."
6. Encourage discussion of the question of what should go out of the curriculum as more technology comes in, or if it is possible, to include technology material so that it so emphasizes the teaching of the existing course material so that little of what is existing needs to be eliminated.
7. More information regarding content of science-technology courses and potential careers in technology should be made available to school counselors through workshops. This will help them to guide students more effectively into appropriate courses and careers.
8. State education departments should make a special effort to assure teachers that the inclusion of technological material in curriculum is not only acceptable but is actually desirable at all levels.
9. The developers and publishers of standardized tests should be encouraged to include technology oriented questions in specific discipline tests. For example, on a recent National Assessment test it was found that only 12 percent of the seventeen-year-olds knew that plastics come from petroleum and only 3 percent were aware that the U.S. mortality rate is worse than that of most western European countries.
10. No major developments of science-technology courses should be planned or funded without substantial planning and funding for broad-scale dissemination and implementation of these materials.

11. Since curricula, attitudes and points of view presented at the secondary school level tend to reflect the disciplines as modeled in the universities, and science teachers tend to teach as they were taught, it is important that new courses on technology be developed at the post-secondary level.

20

APPENDIX G

Report of the Working Group on Informal Education

All individuals can express or develop their interests in science, mathematics and technology through informal education experiences. Science centers, local scientific societies, industries, community groups, etc. can offer a wide variety of one time and ongoing experiences to extend the role of the school. The unique difference is that the individual decides what they want to learn, when they want to learn it and to what levels of sophistication they want to learn it.

The goal is to develop intelligent "consumers" of science and technology. Individuals, who when faced with decisions as voters, value evidence over emotional appeals to help them reach decisions. They make decisions regarding their own health and life-style based on evidence and reasonable personal preferences, after taking into consideration short- and long-term risks and benefits of different decisions. This is contrasted to the individual who is "guided" only by advertising in health and life-style decision making. The goal is to provide information and experience of interest to individuals. This helps them see the value of evidence-based decision making as an effective approach to selecting from the many choices people have to make in regard to themselves and as involved members of society.

Organized centers for informal education in science, mathematics and technology such as science and technology centers where available can also serve a variety of additional functions such as the following:

1. Provide opportunities for career awareness and career exploration for young people through fairs, exposition career days, etc.
2. Provide major exhibitions, lectures and other presentations in science for the public so as to better inform the public and help them to develop a greater understanding and awareness of science and technology and its role in our society.
3. Take a leadership role in locally based teacher training and curriculum development utilizing their trained staffs as part of the necessary instructional and curriculum development leadership teams.

Needs of Superior Students:

One of the more serious problems in education in science, technology, and mathematics is to provide greater opportunities for the gifted, talented or otherwise superior student. These students may, in a short time, go beyond what their school and teachers can provide—apart from the teachers support and expression of interest.

Opportunities for such students are currently available in museums, science and technology centers, zoological parks, botanical gardens and a variety of similar situations. Additional personal and specialized in-depth experiences could be provided for such students by a wide variety of community and industrial organizations and groups. For example, the local Audubon Society or natural history museum could be encouraged to involve such students in their ongoing programs. Local industries could provide summer or school year research orientation and participation experiences. Mechanisms could be developed for helping parents to encourage youngsters with talents in these fields and special equipment such as computers could be made available to those who would not be likely to have them at home.

Apart from the actual experiences, the positive effect brought about by the student sharing his or her interests with concerned adults could be of enormous benefit in encouraging the individual.

APPENDIX H

Report of the Working Group on K-12 Curriculum for Science Education

The group emphasized two of the Commission's goal areas: science literacy and science manpower. Relationships among these goals and the general outlines of a K-12 curriculum to meet the goals were addressed.

Any consideration of K-12 curriculum must be driven by an understanding of the demands put on education in a democracy that is part of a complex technological world. There is demand for scientific skills, attitudes, and knowledge. A technologically-oriented, democratic society cannot exist with large sections of its population ignorant of science and technology. Attitudes, skills, reasoning abilities and knowledge from science are prerequisite to a sense of control over human destiny on the part of the populace. Full science literacy involves the following four components:

- Ways of knowing: What do I know? What is the evidence?
- Actions/Applications: What do I infer? What are the options? Do I know how to take action?
- Consequences: Do I know what would happen?
- Values: Do I care? Do I value the outcome? Who does care?

The group agrees that science literacy is essential for all students. Science manpower requirements must be built upon a foundation of science literacy.

Even for students who take all available science courses, many existing K-12 science instruction programs are not adequate to produce science literacy. For the majority who take very little science, the situation is truly a national crisis.

The following is an illustrative K-12 sequence. While this is by no means the only way to achieve the goals of developing science literacy and science manpower, it serves to illustrate the nature and magnitude of the changes the group believes are needed.

K-6. An integrated, hands-on approach is needed, which focuses on the relationships between humans and the total environment. Problem-solving must be emphasized, including acquisition and analysis of data.

Grades 7-8. In grades 7-8, two primary emphases should be made. First, on human science, including human biology and personal health. Second, attention should be paid to development of quantitative skills in science. Computer-based experiences should be used appropriately to assist in development of quantitative skills that will be needed for more complex, applied problem-solving in grades 9-10. Skill in quantitative analysis of data, application of probability and estimating skills are examples.

Grades 9-10. A two-year sequence, required for ALL students, would address Science, Technology and Society. This course emphasizes problem-solving and scientific reasoning as applied to real-world problems. It integrates knowledge and methods from physics, biology, earth science, and chemistry, as well as applied mathematics. Examples of the kinds of phenomena and science addressed are included in the report from the technology subgroup.

Rationale for placement of this sequence at the 9-10 grade level is that the students need to have acquired certain developmental, math and problem-solving skills which are prerequisite to the complex kinds of problem-solving tasks required in this course. This is a much higher level kind of course than is generally recognized as a "general science" course for non-science students.

Grades 11-12. One and two semester courses in physics, biology, chemistry and earth sciences are provided at this level for students who wish to go on to further academic study in science-related careers. These are not Advanced Placement courses and are not meant to replicate college-level courses. These courses do build upon and assume as prerequisites the skills and knowledge in the various science disciplines that students will acquire in the Science, Technology and Society course in grades 9-10.

LONG RANGE VS. SHORT RANGE

The implications for implementation of a plan such as the one outlined above are major. Science teaching staff would double from the existing staff. Extensive curriculum development and teacher training is required. Full implementation nationwide would probably take about 15 years. However, phases of implementation are possible. Initially, the Science, Technology and Society Course would be only one year on a required basis for all students. The second year would be optional or elective while further materials, curricula and staff are being developed.

APPENDIX I

Report of the Working Group on Integrating Math, Science, Technology

1. When possible, science-technology situations should be used to introduce mathematics topics at all grade levels.

2. Mathematics courses in grades 7, 8 and 9 should introduce (if it hasn't been done previously) and stress probability, proportional reasoning and intelligent estimating.
   Example:
   Is your ten speed bike really 10 speeds?
   Requires—ratios of teeth on gears
   Speed ratio is inverse to force ratio.
   Distance traveled by foot requires measurements which have limits of accuracy and therefore can be used to introduce concept of significant figures when calculations on the calculator give the ratio in 10 "significant" figures.

3. An integrated science-technology course should be the basic science course at grade nine.
   Examples:
   The use of technological systems for earthquake prediction should be part of the earth science component of grade 9 science.
   The operation of the clock thermostat should be used to introduce feedback and control and its value in energy conservation.

Smoke Detector

The examination of the ionization smoke detector for radioactivity and the measurement of that radioactivity at various distances from the source followed by the graphing of the data will help to develop the relationship of intensity of radiation with distance. Comparison of the radiation received 30 inches from the smoke detector by standing under it for 8 hours/day, 365 days per year and that received by a person during one dental x-ray is interesting. Deciding the relative value of knowing that you have a decayed tooth compared to saving your life in case of a home fire is a useful outcome of such.

Acid Rain

If we look at the effect of acid rain on buildings and monuments we learn that while calcium carbonate (marble) is essentially insoluble in water, calcium sulfate and calcium nitrate are very soluble. In the examination of Tables of Solubility we learn that barium sulfate and barium nitrate are not nearly as soluble. If we could replace the calcium ions on the surface of marble with barium the new marble will withstand the ravages of acid rain while developing systems for eliminating acid rain. A laboratory activity capable of being done by grade 9 students will demonstrate that this is possible.

Measurement of the deterioration of gravestones in V.A. cemeteries will also give us data on how the rate of decay has increased over the past 200 years compared to previous periods of time.

"There is an apparent need in technology education for a leadership and coordination function at the national level. The activities recommended earlier are likely to have little impact unless they fit logically into a coordinated group effort of those supporting technology education. We recommend the formation of a national center for leadership in technology/society education. Such a center would probably need to be supported for a number of years and would serve as a continuing stimulus for coordinated activity. It should serve as a clearinghouse for strategies, information, and ideas, and as a pro-active coordinator of research, development, and dissemination activities. One of the first activities of such a center should be a thorough study of resources available in technology/society education. Resources to be sought and organized would include funding sources; existing support groups, institutions, agencies, and individuals who support technology/society education; and materials and techniques which have been developed to aid technology/society education. Subsequent activities would then be designed to coordinate these resources into a viable national effort. We are convinced that such an effort is crucial at this point in our country's development."[1]

[1] From "What Research Says to the Science Teacher," published by NSTA.

APPENDIX J

Report of the Working Group on Technology in Teaching

Science educators are moving rapidly toward the increased use of technology and a recognition of new roles for technology in science and science teaching. Although we examined the potential contributions of several technologies such as computers, educational/instructional television, videodiscs, teleconferencing, computer-based conferencing, and interactive cable, we chose to discuss some recommendations and reservations regarding the use of the microcomputer specifically. This can serve as an example of the promise and problems associated with the use of such new technologies in science education.

The revolution in microelectronics and telecommunications must be used in ways which contribute to the continuing evolution and improvement of science and technology education. A short burst of enthusiasm, even if well placed, will not be of long-term service to students or this nation. Within microcomputing itself, it is all too easy to act as if the equipment and its casual use represent the new panacea for science and technology education—and then subsequently suffer the disillusion and depression which necessarily follow when such lofty expectations are not met. Thus the following recommendations are accompanied by reservations and cautions needed in a time of rapidly changing options in instructional technology.

Computer Applications of Particular Importance in Science and Technology Education:

Recommendations

1. *As a tool for computation.* Have the computer carry out, for example, a statistical analysis which is otherwise too time-consuming or awkward. But students should understand how such mathematics could be done manually, i.e., "what's going on inside the black box." On the other hand, in standard computation such as solving simultaneous equations the computer can be just a "black box."

2. *As a tool for interfacing with laboratory equipment.* Have the computer assist with gathering bench data, displaying it on screen, printer, or plotter, and perhaps analyzing it. But students still need to get first-hand experience, e.g., calibrate and test the equipment, or even do the experiment once without automation, followed by exploration of the variables with further computer interfacing.

3. *As a tool for processing information.* Have the computer organize, graph, and analyze data, or search a database for information. Still students must have enough experience with manipulation of data by hand to understand what is going on inside the computer.

4. *As a tool for creating and testing models.* A computer-generated model can serve as an aid to description, concept-clarification, and problem solving, even though it is not a totally faithful representation of the 'real' system being modelled. Striving for a close match with reality, in fact, is not necessarily appropriate. Too much fidelity in a simulation detracts from its educational value and gives a false impression of the role of simulation. Appropriate abstraction in the model calls attention to important variables and relationships. It's far better to have students examine, criticize, and modify a model than to experience a simulation and mistake it for a totally accurate representation of reality.

5. *As a tool for describing processes, procedures, and algorithms.* Developing computer programs involves basic problem-solving strategies (understanding and defining the problem, identifying sub-problems, seeking solutions, debugging, etc.). The computer offers an environment where new ways of representing complex ideas can be explored. These opportunities go far beyond programming languages such as BASIC, Pascal, and Ada. Changes (qualitative improvements) in software and applications packages are making computer descriptions of phenomena and systems in science and technology more accessible to students.

Additional Considerations and Reservations in Computer Use

1. Computers are important, exciting, and fun. As a result, there is a current tendency to ignore other instructional technologies. Some may appear too narrow in scope or too expensive presently (e.g., intelligent videodisc, computer-based conferencing, interactive cable), but will be economical within five or ten years. Some technologies which may no longer appear 'exciting' (e.g., video tape and computer-assisted instruction) can still help supplement instruction in schools where available teachers lack background in science and science education.

2. Potential computer users should be cautioned not to reject the concept of computer-aided instruction because of shortcomings in present software and equipment. The most certain prediction within the computer field is *change*, and improvements necessary for success in business and consumer markets will benefit education as well.

3. The attitude of science teachers toward student computer skills should be similar to current attitudes toward student mathematical skills. We can establish

some broad expectations regarding the computer skills science students should have, and then be ready to provide instruction or assistance as necessary to support computer uses peculiar to science and technology education. Science teachers' responsibility toward computer education is no greater (nor less!) than their current responsibility toward mathematics education.

4. The problem of access is sufficiently serious that those schools (and homes?) without computers may need outside assistance to provide equal access. It may become necessary to carry out a Government mandate to assure student access to appropriate computing.

5. Appropriate instructional technology must be used within preservice and inservice teacher programs to demonstrate its proper uses as a teaching tool in science and technology education, and to minimize the possibilities of misuse of the technology in inappropriate settings. (Any computer program that can be replaced by a teacher probably should.)

Planning and Implementation

Rational use of the new technologies in teaching must be based on careful analysis and planning within three related areas:

People. A national program must include assistance, support, and education for teachers, administrators, and others making use of new technologies in teaching and learning activities.

Materials. A national program must provide incentives for development of quality materials and software necessary to provide effective instruction through tools such as those listed earlier in this report (computation, instrumentation, modeling, etc.). These tools must be put in the hands of students by teachers possessing appropriate background in the proper use of these materials.

Ideas. A national program must invest in research and long-term development, creating new capabilities and anticipating difficulties in the uses of instructional technology. We need to understand much more about learning, learner-machine interactions, and effective strategies for teaching with, about, and through computers

Technology must be taken beyond the fascinating equipment capable of transmitting, storing, processing, and displaying information. For effective use in education, greater attention is needed to the development of software and materials which can define new computer-based environments for learning. Both systematic and creative approaches are needed to develop, refine, and validate such instructional material.

Within video technology, we can already identify impressive productions which exploit the medium to present important science/technology concepts and involve the viewer in considering their consequences and applications. Video sequences can be found which motivate, inform, and challenge students, and then lead to classroom discussions, field trips, or laboratory work involving students in important learning tasks. Analogous uses of newer technologies in enhancing instruction must be sought and developed, recognizing technology's potentially valuable role as a supplement to (rather than a replacement for) other successful teaching strategies.

Postscript

Educational planners and decision makers (such as Commission members) should obtain a microcomputer typical of current technology to use at home, plus a library of the best available applications programs and supporting materials. In a familiar setting, they should have the opportunity to try the computer and software with family and friends of various ages. They should also participate in a computer-based conference or electronic bulletin board with educators exchanging information and advice on new technology. Of course they should also observe similar technology being used in a school and talk to students and teachers about their experiences and impressions.

APPENDIX K

Report of the Working Group on Curriculum Development

In any science curriculum development it is necessary to provide that science which is basic to modern technological society. Great progress has been made in the development of rigorous courses in the science disciplines taught in secondary schools. Changes in those courses need to be made to bring them up to date with the latest scientific and technological developments. Additional curriculum materials which bear even more on ongoing developments in the sciences and technology and interface with present and future personal and societal needs and career awareness, also need to be developed. Many of these changes will be in the context in which concepts, principles, generalizations or theories are taught.

While there is essential agreement on which concepts, principles, generalizations and theories should be taught, the context and emphasis will in some cases vary from region to region or even within regions. It is important, therefore, that local groups as well as national groups be involved in revising and developing curriculum in the sciences. In order to meet local needs as well as provide curriculum which does in fact speak to all of that which is basic to modern technological society, it is necessary to have a viable system for developing curriculum.

1. At the national level a set of non-prescriptive guidelines accompanied by a large set of illustrative examples will be developed. This development would take place at a number of regional centers which would be commissioned for that purpose.

   Staff at such a center would include personnel with established credentials in one or more of the following areas: subject matter, research in science education, curriculum development, teacher education, teaching science at the various levels, and curriculum implementation.

2. In order to have the optimum opportunity for infusing the curriculum into the classroom, it is important that the local group indicate a commitment to trial and implementation of the curriculum materials which are developed by the local groups.

These local groups, which would be organized in a variety of ways, would be asked to write proposals explaining among other things the needs as they see them and the system for implementation. They would meet during the summer for a period of six to eight weeks with resource people either at one of the regional centers or at a local center which has been designated for curriculum development. The science teachers would be paid a sum which is equal to or greater than their academic salary for the same period of time for this development.

During the ensuing year some of these people would be assigned and paid for the additional responsibility of continuing curriculum developing at the center and assisting teachers at the local level with the implementation of the new materials.

This system will encourage and reward outstanding teachers and serve as a basis of re-education of all who are involved.

26

APPENDIX L

Report of the Working Group on Teacher Preparation—Elementary K-8

All teachers must be qualified and certified to teach science, K-3 Science Specialist monitors and assists the regular classroom teacher who teaches science.

4-6 Science Specialist in one of four modes:

1. Trained Science Specialist in each classroom.
2. Specialist trades with other teacher. (science—social studies switch).
3. Moving Science Specialist to each class.
4. Moving classes to Science Specialist.

7-8 Trained Science Specialist in each science class.
Teacher education:

1. Strong science courses—lab based.
2. Early opportunity for observing and participating in science teaching. Don't wait till the last year.
3. Child development: Psychology of the child through adolescence.
4. Training in the use of technology.
5. Method courses in the application of knowledge on child and adolescent development to science education.

Elementary Teacher Preparation K-8
Characteristics of Pre-school/In-service

1. Hands-on experiences.
2. Activities that enhance questioning.
3. Developing creative skills.
4. Developing problem-solving skills.
5. Understanding the use of technology.
6. Understanding the emerging adolescent.

Summary

Teachers should understand, use, and apply the skills in science as stated. (Skills being defined as concepts and process interwoven.) Pre-service education should include training in the practicalities; e.g.

1. Bulletin boards.
2. Learning centers.
3. Managing equipment: using, storing, repairing, and managing students using the equipment.
4. Use of resources: Development of professionalism through an awareness of professional organizations and educational publications and how to gain access to them.

In-service education should include participation in curriculum planning and/or writing curriculum materials by teachers.

Long Range Plans

1. Create a study on how one can train an elementary teacher in 120 semester hours, including the necessary competencies in science, mathematics, language arts, social studies, etc. as well as psychology and methods courses. Is it possible to do all of this well or not? What school background for the prospective elementary teacher would have to be presupposed?

Short Range Plans

1. Look at the characteristics of exemplary programs for the preparation of K-8 teachers such as those identified by "Search for Excellence."
2. All teachers should have some training on the use of calculators/computers.
3. All teachers aware enough of research in science education and be familiar enough with education technology to be comfortable in carrying out action research in the classroom.
4. In-service education of science teachers must be designed so that required professional paid continuing education will be maintained for the next couple of decades.
5. Such education clearly separates into two clienteles:
   (1) Those who must be trained to be qualified to teach science- or present science teachers who are qualifying to teach new subjects.
   (2) Those who are qualified and are updating their qualifications.

APPENDIX M

Report of the Working Group on Teacher Preparation Grades 6-12

Some type of differential pay in money, time, or other form of remuneration needs to be adopted in order to attract and hold qualified science and math teachers. We strongly recommend that a subcommittee meet after these deliberations with leadership from the AFT and NEA to discuss creative ways to approach the subject of differential pay.

A few centers across the country should be identified or created as models of pilot programs of exemplary science education at all levels. These centers should include university personnel in the content areas, science curriculum experts, science educators, learning theorists, communication specialists, master teachers, exemplary school districts, etc. Such centers could eventually serve as a nucleus for expanded teacher training programs.

It is strongly recommended that two levels of inservice science education programs be immediately implemented:

(1) to update teachers who originally received adequate training but are now lacking in new content knowledge, use of new technology, and use of methodology in relating science curriculum to the community,

(2) to train teachers who have little or no preparation in science content or science teaching strategies in the area(s) to which they have been assigned.

It is imperative that a permanent national inservice science education program be put into place as a long term investment to continually update and improve science education. The science curriculum should be revised to better relate science with the community and other subject areas. Teachers must be continually trained and retrained to meet the needs of students living in a changing technological world.

Support for science curriculum change and development as well as teacher training to manifest this change is urgently required.

APPENDIX N

Report of the Working Group on Support for Implementation and Change

Preamble

This report is prepared under the assumption that federal funds exist both in 1983-1984 and in future years for the initiatives and program recommendations likely to emerge from National Science Board Commission reports. We are particularly concerned that those funds be disbursed in ways which address the concerns of highest priority, and not on the basis of political or other irrelevant interests.

Recommendations

1. Support should be provided for the creation and operation of a National Center for Science Education. Such a Center would have the advantage of concentrating talent and resources, without the constraints and limitations found in schools or school districts. Thus, innovations in scope, sequence, and content, as well as apparatus and resources could be all brought to bear on the problems of science education in one Center. The Center could include a materials development center and research library, along with a K-12 demonstration and research school, in which the best possible teachers, facilities, equipment, etc. could be used with a representative group of students.

   Such a Center could be supported by a mixture of public and private funds. The private sector could also participate by contributing state-of-the-art electronics, computers, and other material and equipment. This Center could operate under the oversight of a "Joint Council" of the type being proposed by the National Science Teachers Association (modeled after the Joint Council on Economic Education). The National Center could serve as a national repository for advice and information on science education.

2. Pertinent data on all aspects of science education should be collected annually by the Science Resources Studies Group of the National Science Foundation (NSF). These data should be analysed and their highlights made public. The data collection should be maintained and results stored in some permanent fashion so that the important information they contain is continuously available.

3. There was strong feeling that the National Science Foundation, which supports through its basic research program, the creation of knowledge, and which has strong links with scientists and science education personnel in universities, colleges, and industry, is the agency through which support for science education programs should be funded. There was also much concern that the FY 1983 appropriation be allocated with a proper balance over the areas of priority identified by this meeting and by the National Science Board Commission. Thus, we recommend that the following resolution, endorsed by this meeting, be communicated to appropriate officials of the NSF and elsewhere by the NSB Commission:

   > Be it resolved that this "Conference on Goals for Science and Technology Education" calls for immediate approval of guidelines for the $15 million of NSF Science Education funds for FY 1983. These guidelines should insure a proper balance among science education research and development, computer utilization, public awareness of science, and teacher institutes, with at least half of the funds designated for the support of teacher institutes. Furthermore, we strongly recommend that most future support for research and development in science education, as well as support for teacher training, be provided through the National Science Foundation.

4. Within each state an individual or group should be identified to provide leadership for the improvement of mathematics, science and technology education. In most instances, the State Science Supervisor or the equivalent would provide this leadership. Funding should be made available for the necessary statewide needs assessment, resource identification and data collection. This joint state group could work with the Joint Council proposed by NSTA as described in (5) below.

5. An important feature of the Joint Council being proposed by NSTA is the state structure which is also loosely modeled after the Joint Council on Economic Education.

   The agency identified in (4) above would be encouraged to set up a joint state organization, with representation from science, education, business, industry and labor. Such an organization would provide state-level leadership and enter into cooperative efforts to improve precollege education in mathematics, science and technology. These joint state groups would be represented on the Joint Council.

6. NSF FY 1983 appropriated funds for science education should be allocated for first-phase support of high priority initiatives identified by this "Conference on Goals for Science and Technology Edu-

cation." In this way, many of the efforts which are needed could begin as early as Fall 1983.

7. Cost sharing and matching requirements of NSF guidelines should be small and flexible. Need and merit should be criteria that are included in funding considerations.

8. There were many excellent materials development projects over the past ten years which did not include a dissemination component. Some of these efforts resulted in production of fragmented sets of materials; others produced entire sets. There are other sources of such materials. Funding should be provided to examine, evaluate, revise where appropriate, complete, and disseminate those materials that address goals appropriate to the 80's.

9. There must be a careful balance in support of national materials development efforts and the local efforts to select, assemble, adapt, and sequence high quality curricula. There must be local training and familiarization. There also must be strong involvement of teachers in national efforts. The Joint Council would provide a national forum for discussion and coordination of the many materials development efforts that will arise.

APPENDIX O

Report of the Working Group on Science Education and the Physically Disabled Individual

The educational emphasis that is necessary for the disabled is one of "Enabling the Disabled rather than Capping the Handicapped."

Therefore, for disabled individuals just like their non-disabled peers, it is necessary to transmit and develop the information and understanding that is necessary for individuals to become independent, contributing members of society. In addition, and more important, it is necessary to help individuals, disabled or not, *to learn how to learn*. Then whether it be in the world of work or as participating citizens in our democracy, individuals will be able to adapt to changes, process and analyze new information, and make intelligent decisions based on the evidence.

Our whole society is becoming more dependent on science and technology everyday. We expect our citizenry to make a wide variety of science and technology-based decisions in the world of work and in life generally. Therefore, science and related fields have become extremely important in the education experience of all learners. For disabled learners, science instruction starting at an early age and continuing throughout their school career takes on added importance for the following reasons:

1. Science emphasizes hands-on experience and exploration of the environment, both physical and biological. It can help to fill some of the experimental gaps in the background of many physically disabled individuals. Whether these gaps have evolved because of extensive hospital stays, overprotectiveness of schools or parents, or a variety of other reasons, these hands-on experiences are essential in developing knowledge and understanding of one's environment and one's personal relationship to it. Such understanding is extremely important in helping to develop the individual's independence and overall positive self-image.
2. Recent scientific and technological advances have provided the tools (computers, talking calculators, control systems, versabraille hook-ups to computers, TTY telephone systems, etc.), which can help to mitigate the limitations imposed by a physical disability. This can help enable disabled individuals to be independent contributing members of society. In order to effectively use these technological devices, disabled individuals need first to know about them. Also helpful is a variety of experiences exploring variables, using equipment and materials, machines and related devices. Many of these technological devices involve organizing and inputting information. Science instruction with its emphasis on making observations, collecting and organizing evidence, and coming to conclusions can be significantly helpful in developing the individual's psychological and manipulative readiness for using technological devices.
3. Job opportunities in the future for all individuals will require greater knowledge and understanding of technological devices and how they work. The computer will become an important part of many jobs in the future. Because of technological advances in alternate ways for individuals to use computers, many of these jobs are available even to the seriously disabled if they have the necessary background and training and perhaps more importantly, self-confidence to seek the position. Early experience-based science education can help disabled individuals to develop the skills and attitudes necessary to effectively take their place in the world of work as independent contributing members of society.

If concern for the physically disabled sounds too altruistic to some in times when "hard economic decisions" are necessary, it is important to note that an independent, self-reliant disabled individual can be a full contributing member of the society. The alternative is the totally dependent individual who has to be cared for indefinitely at costs per year far in excess of the entire cost to provide an effective science program. Science education cannot solve all problems but it can make a significant contribution. From humane and economic points of view, we can do no less than provide disabled individuals and their peers with the best possible science program. To do less is cheating disabled individuals and ourselves.

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APPENDIX Q

AGENDA

Conference on Goals for Science and Technology Education, K-12
Washington, D.C. March 11-13, 1983

Friday, March 11

8:30 p.m. Plenary Session

- Statements and discussion about the purpose of the conference
- Brief reports on recent studies and reports on the status and needs of science and technology education and on learning/teaching methods

Saturday, March 12

9:00 a.m. Plenary Session

- Discussion of the agenda
- Discussion about type of information needed from groups

9:30 a.m. Group Meetings: Elementary School Science, Biology, Chemistry, Physics, Engineering

2:00 p.m. Plenary Session

- Reports from groups
- Organization of afternoon groups on other science areas, overlapping areas, special emphasis for different students, etc.

3:30 p.m. Group Meetings

Sunday, March 13

9:00 a.m. Plenary Session

- Reports from groups
- Discussion about educational feasibility of suggested programs and teaching problems

11:00 a.m. Groups meet to draft reports

2:00 p.m. Final Plenary Session

- Decision on conference recommendations
- Discussion about conference report format

3:00 p.m. Group report-writing until departure times

34

APPENDIX R

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