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ABSTRACT

This monograph summarizes selected major activities, trends, issues, and recommendations related to curriculum, instructional materials and instruction related in science education that have been documented in the literature. The technique used for selecting trends, issues, and recommendations was to identify relevant literature that had published during recent years and selected documents referenced in these sources; determine the agreement or disagreement regarding trends, issues, and recommendations; select those that appeared most frequently and/or those that were indicated as possibly most influential; and select examples of curricula, programs, materials, and instruction to illustrate trends, issues, and recommendations cited. Sections include: (1) "What Are the Conditions Creating a Demand for Change?"; (2) "What Is the Status of Science Education in Elementary and Secondary Schools?"; (3) "Curricular Frameworks: Goals, Content, and Experiences for Precollege Science Education"; (4) "Research Related to Learning, Curriculum, Instructional Materials, and Instruction"; (5) "Development and Implementation of Curricula and Instructional Materials for Precollege Science"; and (6) "Summary and Recommendations for the Reform of K-12 Science Curriculum, Instructional Materials, and Instruction." A list of 136 references is included. (KR)

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TRENDS AND ISSUES IN SCIENCE EDUCATION: CURRICULUM AND INSTRUCTION

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Table of Contents

Preface

This monograph summarizes selected major activities, trends, issues and recommendations related to curriculum, instructional materials and instruction related to K-12 science education that have been documented in the literature during the past few years.

The technique used for selecting trends, issues and recommendations was to: (1) identify relevant literature that had been published during recent years and selected documents referenced in these sources; (2) determine the agreement or disagreement regarding trends, issues, and recommendations; (3) select those that appeared most frequently and/or those which were indicated as possibly most influential; and (4) select examples of curricula, programs, materials and instruction to illustrate trends, issues and recommendations cited.

A selected bibliography used in preparing the publication is included at the end of the monograph.

I. WHAT ARE THE CONDITIONS CREATING A DEMAND FOR CHANGE?

The recent science education literature stresses the need for change in the content of science (the curriculum) and the way science is taught (pedagogy).

Conditions creating a demand for change and some of the changes desired have been documented in reports including A Nation at Risk (National Commission on Excellence in Education, 1983); Educating Americans for the 21st Century (National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983); Academic Preparation for College (College Board, 1983); What Science Is Most Worth Knowing? (American Association for the Advancement of Science, 1987); Science for All Americans (American Association for the Advancement of Science, 1989). Other publications documenting the need for change are One-third of a Nation (American Council on Education, 1988), America in Transition (National Governors Association, 1989), America's Next Crisis (Aerospace Education Foundation, 1989), Investing in People (U.S. Department of Labor Commission on Workforce Quality and Labor Market Efficiency, 1989), Workforce 2000: Work and Workers for the Twenty-First Century (Johnston, William B. and Packer, Arnold E. (Eds.), 1987), Educating Scientists and Engineers, Grade School to Grad School (U.S. Congress, Office of Technology Assessment, 1988), and Science and Engineering Indicators (National Science Board, 1987, 1989).

Conditions Creating a Demand for Change

Conditions creating a demand for changes in precollege science education include seven main areas. These are: (1) changes in the world society; (2) changes in international competitiveness; (3) changes in the role of technology; (4) changes in the need for science knowledge and skills; (5) changes in the sciences and how they are used; (6) research on learning and instruction; and (7) a discrepancy between changes desired and current school programs and student achievement (the current status of precollege science).

Changes in the World Society and the United States

Several writers including Naisbitt (1982), Toffler (1985), and others have indicated that the United States and the developed world are shifting from an industrial to an information society. The new society uses information for much of the capital and raw material, and communication as a new means of production. Change is being accelerated by developments in communication and computer technology. The older industrial economy is changing, and new information-based economies are being developed.

These changes have created the need for individuals with the ability to continue to learn, to adapt to changing conditions, to produce new knowledge, and to acquire knowledge and skills needed in the current societal transition.

Demographics are also changing in the United States. An increasing percentage of our work force will come from minorities and white females, rather than white males. Appropriate science education needs to be provided for all students if the United States is going to have an adequate work force for the 1990's and beyond.

Changes in International Business, Marketing, and Competitiveness

During the past 20 years there has been a significant change in the economic competition among the nations of the world. Many developed and developing countries are becoming more productive and developing marketing programs that are global in scope. These countries are also developing educational programs to produce better educated work forces and citizens.

Data indicate that United States students are not achieving in science as well as students from many countries with which the United States competes or with which it will compete for world markets (Jacobson, 1988; Lapointe, et. al, 1989). United States business and industry indicate at the current time that many of the workers whom they employ are not educated sufficiently in science and related thinking skills. As a result, they spend billions of dollars to educate workers to a knowledge and skill level they need. In addition, some people believe more people are needed in the science pipeline to provide a sufficient number of quality people at advanced degree levels for higher education, business and industry, and government.

There is a need to provide all students with scientific knowledge and skills they will require in the new global environment. Preparing students to a higher level of achievement and maintaining more students in the science pipeline are also important needs.

Changes in the Role of Technology and Use of Technology in Schools and in Society

The remarkabledevelopment of new technology during the past 15 years has changed how science is used, what science is important, and how science is pursued. Major changes should therefore be made in the way science is taught by incorporating the use of computers and other new technology into its teaching and learning. Major changes should also be made in the curriculum, both in terms of the content taught and how the content is presented.

Technology should be used to illustrate how information is currently obtained and analyzed in science to help prepare students for the work and non-work environments in which they will be using technology. Technology should also be used to individualize instruction to help all students learn more effectively and efficiently, to understand concepts better, and to learn to solve problems more effectively.

Changes in the Need for Science Knowledge and Skills for Everyday Living and for Jobs

Major changes have taken place and will continue to occur in terms of knowledge and skills required for the work force. Scientific and technical knowledge and skills are increasingly needed for many jobs. Knowledge of computer-related concepts and processes are also required for many jobs, and an awareness of these concepts and processes is helpful in many more positions.

A higher level of scientific knowledge and skills is also needed for everyday living and for effective citizenship in our society. The ability to analyze and interpret information in the mass media, to use and analyze information contained in a variety of databases, to make effective work and business decisions, and to make everyday decisions in the home and as a consumer requires more depth in scientific and technical knowledge than are frequently taught and better skills than are frequently learned.

Changes in the Sciences and How They are Used

During the past two decades there have been many changes and new developments in science and technology. Science has become increasingly multidisciplinary, with an increased use of technology, and scientists have become involved in more team-based research. In addition, scientific advances have created increased emphasis on decisions regarding the applied use of scientific knowledge such as those related to genetics, medicine, health, and the environment.

Research on Learning, Curriculum, Instructional Materials, and Instruction

Knowledge of how students learn and how the curriculum, instructional materials, and instruction can help improve learning continues to increase. Fundamental ideas regarding how students construct their own knowledge, the role and sequencing of materials, the effectiveness of some instructional procedures, and the use of technology require changes in science curricula and instruction. Relatively few schools are using materials and providing instruction in ways that are consistent with research on effective and efficient learning.

A Discrepancy between Changes Desired and Current School Programs and Student Achievement

Data presented in Section 2 summarize some of the information on student achievement and school practices in the U.S.A. Evidence is clear that many students are not achieving either traditional goals or new goals. Evidence is also clear that many school programs are not emphasizing or attaining many of the important traditional goals or newer goals.

Trends and Issues

These changing conditions have created a need to examine past and current goals, curricula, and programs for precollege science to determine changes that are desired and possible. Educational research has been developing a knowledge base for science education that provides a basis for the improvement of curricula, instructional materials, and instruction. The changing conditions and new goals also have created the need for additional research to help guide future efforts.

Trends

1. There is general consensus that changing conditions create a need for substantial modification of precollege science education in the United States.

2. There is growing consensus on the conditions creating a need for change.

Issues

1. What science education is needed for all students at the K-12 level?

2. What science education should be provided for special groups at the K-12 level?

3. What changes in current precollege science education are needed to respond to these conditions?

4. Is there a need for mechanisms and processes to determine how successful educational interventions are providing solutions?

5. Are there other major conditions that should influence precollege science education that should be considered?

6. Are there emerging conditions that should be considered?

7. These conditions are not all unique to science education. How should the science educational community and others organize to determine what should be done in a systematic way to address these conditions?

8. What should be the roles of (1) federal, state, and local governments, and (2) the private sector in guiding and developing changes in precollege science programs?

II. WHAT IS THE STATUS OF SCIENCE EDUCATION IN ELEMENTARY AND SECONDARY SCHOOLS?

Analyses of student science achievement indicate that American students are not learning several concepts and skills as well as desired. Analyses also indicate the U.S. students are not achieving as well on many desired concepts and skills as students in several other industrialized countries.

Additional data indicate that the science curriculum, instructional materials, and instruction do not introduce new concepts as early as those in some other countries nor provide concepts in as much depth and with opportunities for spaced learning. Data also indicate that some of the desired concepts and skills do not receive sufficient emphasis in U.S. curricula, instructional materials, and instruction and that the time U.S. students are involved in science instruction is less than the time students in several other industrialized countries are involved in instruction.

Recent data indicate that most U.S. schools follow traditional instructional patterns, provide little hands-on instruction, and make relatively little use of technology. Very few schools have curricula especially designed to capitalize on the useful features of hands-on instruction and new technology throughout their programs.

Achievement

National Assessment of Educational Progress (NAEP)

National Assessment of Educational Progress (NAEP) tests (National Assessment of Educational Progress, 1988) were given in 1973, 1978, 1982, 1986, and 1988. Science test scores for age nine have ranged between 220 and 230. Proficiency scores for age 13 have shown a general upward trend with scores ranging from the high 240's to the high 250's. Proficiency scores for age 17 showed a decline from 1973 to 1982, with improvement in 1986 and 1988; the 1988 scores were about the same as the 1973 scores at the mid-290 level.

In general, gains have been made on items reflecting process skills and general concepts. Downward trends have generally been on items measuring higher-order learning skills, applications, and problem solving.

The achievement gap between advantaged and disadvantaged groups has narrowed with gains by Blacks (Westat, Inc., 1988). Achievement scores of Hispanic students have not shown the same gains; this is possibly due to an increase in the number of students for whom the English language was not their first language.

Achievement by males was slightly higher than that for females for ages 13 and 17. Nine-year-old girls had higher mean scores than did boys.

International Assessments

U.S. students have not done well on science tests when compared with other major industrial countries (Jacobson and Doran, 1988; Miller, 1986; June, 1986, and Helgeson, 1988). Analyses of data obtained in the Second IEA study tested students in the fifth, ninth, and twelfth grades in 16 countries.

U.S. fifth-graders ranked at about the median among 15 countries analyzed. Ninth-grade students were ranked with five other countries at the bottom of the rankings. U.S. students who had completed biology, chemistry, and physics ranked in the lower third on tests in each of these areas. When 1986 scores were compared with 1970 scores, fifth-grade scores were about the same, ninth-grade scores declined, and twelfth-grade scores improved.

Data obtained indicate fifth- and ninth-grade students were successful at tasks requiring manipulative skills, but less successful on higher cognitive skills such as investigating, critical-thinking, synthesis, and problem-solving. Ninth-graders also had low scores on application items.

National Elementary and Secondary Science Enrollments

What sciences have American students been experiencing? Reports from several studies provide some general information.

Table 2.1 compares the percentage of high school graduates who took selected science courses in 1982 and 1987. (Westat, Inc., 1988).

Table 2.2 compares the percentage of high school graduates by sex who took selected science courses in 1982 and 1987 (Westat, Inc., 1988).

Table 2.1

Percentage of High School Graduates
Who Took Selected Science
Courses, 1982 and 1987

Course Taken	1982	1987
Biology	75.3	88.3
Chemistry	30.8	44.8
Physics	13.9	19.5

Source: Westat, Inc., 1988

Table 2.2

Percentage of High School Graduates
Who Took Selected Science Courses, by Sex
1982 and 1987

Courses	Male	Female
1982 Graduates		
Biology	73.3	77.1
Chemistry	31.7	30.0
Physics	18.2	10.0
1987 Graduates		
Biology	88.5	90.8
Chemistry	46.3	44.5
Physics	25.3	15.0

Source: Westat, Inc., 1988

Enrollment increases from 1982-1987 were significant at the .05 level for both males and females for all courses. Enrollments were approximately the same for males and females in biology and chemistry. While the percentages of both male and females enrolled in physics increased from 1982 to 1987, more males enrolled in physics.

Preliminary data for 1987-88 and 1988-89 indicate enrollments in chemistry and physics have increased slightly (Council of Chief State School Officers, 1989). The continued increases appear to be due to new and continuing local, state, and college and university requirements.

Table 2.3 compares the percentage of high school graduates who took selected science courses in 1982 and 1987 by race and/or ethnic background (Westat, Inc., 1988). Enrollment increases between 1982 and 1987 were significant at the .05 level for all groups of students for all three courses. Enrollments for Asians was the highest for all three courses; Whites had the next highest enrollments.

Table 2.3

Percentage of High School Graduates Who Took Selected Science Courses, by Race/Ethnicity, 1982 and 1987*

	White	Black	Hispanic	Asian
1982 Graduates				
Biology	77.3	70.9	67.2	82.2
Chemistry	34.2	20.5	15.4	51.4
Physics	16.0	6.9	5.6	33.8
1987 Graduates				
Biology	91.0	84.7	85.9	93.3
Chemistry	48.0	30.3	31.8	72.3
Physics	21.1	10.6	11.2	50.0

Source: Westat, Inc., 1988

*While the percentage of Asian students enrolling in science courses is high, the actual number of students enrolling in science courses is low because Asians comprise a small percentage of the total school enrollment.

Table 2.4 compares the percentages of high school graduates by track who took selected science courses in 1982 and 1987 (Westat, Inc., 1988).

Table 2.4

Percentage of High School Graduates Who Took Selected Science Courses, by Academic Track, 1982 and 1987

	Track		
Science Courses	Academic	Vocational	Other
<u>1982 Graduates</u>			
Biology	91.8	58.3	62.2
Chemistry	59.2	5.8	9.6
Physics	30.0	1.4	1.7
<u>1987 Graduates</u>			
Biology	95.8	75.3	77.6
Chemistry	67.3	4.6	12.4
Physics	31.7	0.9	0.9

Source: Westat, 1988

Enrollments of students in the Academic Track increased significantly between 1982 and 1987 at the .05 level. Enrollment in the Vocational Track increased significantly in biology and enrollments in the Other Track increased significantly at the .05 level in biology and chemistry.

Table 2.5 provides data on the number of credits earned by high school graduates in 1982 and 1987 (Westat, Inc., 1988). The data indicate that the average student earned about one semester more credits in 1987 than in 1982.

Table 2.5

Average Number of Credits Earned by
High School Graduates in Various Subject Fields,
1982 and 1987

Subject Field	1982 Graduates	1987 Graduates	Change 1982-1987
English	3.8	4.05	+0.25
History	1.68	1.91	+0.23
Social Studies	1.42	1.44	+0.02
Mathematics	2.54	2.98	+0.45
Computer Science	0.11	0.42	+0.31
Science	2.19	2.63	+0.44
Foreign Language	1.05	1.47	+0.44
Non-Occup. Voc. Ed.	1.84	1.66	-0.19
Occup. Voc. Ed.	2.14	2.09	-0.05
Arts	1.39	1.41	+0.02
Physical Education	1.93	2.00	+0.07

Source: Westat, Inc., 1988

Opportunity to Learn

Several studies (Jacobson and Doran, 1988; Anderson, et. al., 1982; Lapointe, et. al, 1989; Oakes, 1987; IEA, 1988; and others) have indicated that studying specific content, prior knowledge (having studied content), and time for learning the subject relate to achievement.

National Data on Time Devoted to Science in Schools

Approximately 25 states had requirements related to the amount of time required for elementary school science as of 1989. Recommendations ranged from 20 to 30 minutes per day for grades K-3 and from 35 to 45 minutes per day for grades 4-6. The average reported time was about 19 minutes per day in grades K-3 and about 38 minutes per day in grades 4-6 (Weiss, 1987).

Science recommendations for grades 7-8 varied from 45 to 60 minutes per day. The average reported time was about 45 minutes per day in grades 7-8.

In 1988 it was estimated that schools required an average of two years of science for high school graduation. This was up from 1.5 years in 1982 and 1.8 years in 1985 (Science and Engineering Indicators, 1989).

In 1986 nearly all high schools offered biology and nearly all large and medium-sized high schools offered chemistry. About 9 percent of the schools, mostly small rural schools, did not offer chemistry. Although most schools offered physics, about 19-20 percent did not. Most of these schools were also small rural schools (less than 800 students). While many schools offer such courses as chemistry and physics, some of these schools do not teach the courses because of lack of interested or available students.

The percent of students who graduated having enrolled in various courses was presented earlier in this section.

Comparisons of Time for Science in K-12 Education for the U.S. and Other Countries

Science requirements in the other countries tend to be higher, especially from grades 4-12. The amount of science taken by most students in major industrialized countries is nearly double our elementary requirements and substantially exceeds the time for science courses taken by U.S. students in grades 9-12. In addition, several industrialized countries such as the U.S.S.R. and Japan require sequences of chemistry, physics, and biology for several years (Aldridge, 1989; Jacobson and Doran, 1988; Science and Engineering Indicators, 1987; and Science and Engineering Indicators, 1989).

Inclusion of Topics in U.S. Textbooks

Data from research studies on materials and instruction (Science and Engineering Indicators, 1987; Science and Engineering Indicators, 1989; Weiss, 1987; Miller, 1986; and Jacobson, et. al, 1986) indicate that science textbooks and programs have not been standardized through grade 8. Beginning with grade 9 through grade 12, there is more standardization of textbooks and courses (biology, chemistry, physics, earth science, physical sciences, and advanced sciences).

Textbooks used most frequently have been identified by Weiss (1987) and others and instructional emphases have been identified by Weiss (1987), Miller (1986) and Jacobson (1987).

Many students, nearly 50 percent, take no science after grade 10. They frequently have no physical science course experience after grade 9.

Emphasis on applications of science, science and technology, and societal aspects of science have usually been limited in most textbooks and instruction.

Correlates of Science Achievement from National and International Studies

Analyses of assessment data, both U.S. and international, provide a number of variables that correlate with science achievement. The following variables have been identified:

1. Students who have taken more courses in science generally have scored higher on general achievement tests on science than those who have taken fewer.

2. Opportunity-to-learn (amount of time the student's teachers have emphasized or taught the content) has correlated positively to increased achievement in science. International studies strongly support this correlate: highest ranking countries on opportunity-to-learn generally had the highest ranking scores.

3. Recency of study (use of information) has correlated with increased science achievement. This variable relates also to opportunity-to-learn. The amount of recent study also has related positively to achievement.

4. Depth of coverage relates positively to science achievement on content covered.

5. Students whose parents had higher levels of education generally had higher levels of achievement.

6. Students whose parents encouraged them to take science courses tended to have higher achievement.

Trends and Issues

Data reported and analyzed in several studies provide an indication of the status of science K-12 programs, opportunity to learn, enrollments, and achievement in U.S. schools. Studies also provide comparisons of the U.S. with programs, achievement, and instructional emphasis in other countries.

Trends

1. Achievement tests indicate U.S. students are not learning many desired concepts and skills.

2. Trends in achievement scores for U.S. students indicate scores have been within a close range of scores for each grade level from 1978-1988. There have been no substantial increases or decreases.

3. Achievement scores for Blacks have increased but a substantial gap still exists between their scores and those of Caucasians.

4. Achievement scores for Hispanics have not shown the same gains as those for Blacks.

5. The percentage of students enrolled in secondary school science courses has increased during the past eight years. The percent of males and females increased significantly for all courses.

6. International assessments indicate U.S. students are not achieving in precollege science as well as students in several other industrialized countries.

7. Analyses of achievement data from the U.S. and other countries identify several correlates related to higher achievement scores and suggest some possible modifications for U.S. programs that might help improve achievement scores.

Issues

1. Do the assessment tests cited in this section represent the important science concepts and skills? If not, how can national assessment instruments be developed to evaluate desired learning?

2. If the assessment instruments are valid, what changes in U.S. science programs will provide better achievement for all students?

3. How can the schools, the home, and the community work together to enable and to encourage more minority students to continue their study of science?

III. CURRICULAR FRAMEWORKS: GOALS, CONTENT AND EXPERIENCES FOR PRECOLLEGE SCIENCE EDUCATION

Section II identified trends and issues related to achievement, enrollments, and courses in precollege education. Among the issues raised were the appropriateness of the curriculum goals and whether or not the curriculum was providing appropriate content and skills for today and for the future.

Several reports since 1980 have been produced by organizations and individuals that identify desired goals for precollege science education and science knowledge and skills recommended. Most of these recommendations are based on the changing conditions identified in Section I. Among the reports have been The Mathematical Sciences Curriculum K-12: What Is Still Fundamental and What Is Not (Conference Board on the Mathematical Sciences, 1982), Academic Preparation for College (College Entrance Examination Board, 1982), Educating Americans for the 21st Century (National Science Board, 1983), Science and Technology for the Elementary Years: Curriculum and Instructional Frameworks (National Center for Improving Science Education, 1988) Science Achievement in the United States and Sixteen Countries (Jacobson and Doran, 1988), Getting Started in Science: A Blueprint for Elementary School Science Education (National Center for Improving Science Education, 1989), Science for All Americans: A Project 21 Report on Literacy Goals in Science, Mathematics, and Technology (American Association for the Advancement of Science, 1989), Essential Changes in Secondary Science: Scope, Sequence, and Coordination (Aldridge, 1989), New Designs for Elementary School: Science and Health (BSCS, 1988), and Science Achievement in Seventeen Countries (International Association for the Evaluation of Educational Achievement, 1988).

The science education community, with strong leadership from the AAAS and the NSTA and with substantial support from the federal and state governments and private foundations, has developed curricular frameworks for science education that provide guidelines for the development of science programs. The AAAS Project 2061 activities have identified suggested content and instructional and evaluation patterns. The NSTA S, S and C Project has identified desirable characteristics for a curriculum and for instruction.

Several states including California, New York, Michigan, Georgia, Wisconsin, and Oregon have developed state frameworks for precollege science education that are influencing local curriculum developments and influencing activities of publishers, test developers, and regional and national curriculum projects.

Other groups such as the National Center for Improving Science Education and BSCS have also been active in developing their own guides and frameworks and also adapting guides and frameworks to fit the recommendations of Project 2061.

Curriculum development programs have also developed frameworks. Most of these have been for elementary or middle school grades.

As a result of these reports, national organizations, commissions, states, and consortia have developed frameworks for precollege science that include goals, content, and experiences. Selected frameworks and their goals, content, and emphases are described.

Science for All Americans - Project 2061

This project, developed by the American Association for the Advancement of Science (AAAS), is designed to provide answers and possible solutions to several questions. Questions addressed included the following: (1) What are the content and skills of scientific literacy?; (2) What should graduating high school seniors be expected to know and do? (3) How can scientific literacy be achieved nationwide?

Phase I focused on the substance of scientific literacy. Its purpose was to establish a conceptual base for reform by spelling out the knowledge skills and attitudes all students should acquire as a consequence of their total school experience from kindergarten through high school. Science for All Americans and the reports of the scientific panels are the chief products of this phase.

Project 2061's national council identified six dimensions of scientific literacy. They are:

1. Being familiar with the natural world and recognizing both its diversity and its unity;

2. Understanding key concepts and principles of science;

3. Being aware of some of the important ways in which science, mathematics, and technology depend upon one another;

4. Knowing that science, mathematics, and technology are human enterprises and knowing what that implies about their strengths and limitations.

5. Having a capacity for scientific ways of thinking; and

6. Using scientific knowledge and ways of thinking for individual and social purposes.

Knowledge, skills, and attributes related to science were also identified in a series of reports. Content selected had to meet five criteria: (1) utility, (2) social responsibility, (3) intrinsic value of knowledge, (4) philosophical value, and (5) childhood enrichment.

The national council's recommendations cover a broad array of topics. Many of these topics are already common in school curricula (for example, the structure of matter, the basic functions of cells, prevention of disease, communications technology, and different uses of numbers). However, the treatment of such topics tends to differ from the traditional in two ways.

One difference is that boundaries between traditional subject matter categories are softened and connections are emphasized. Transformations for energy, for example, occur in physical, biological, and technological systems, and evolutionary change appears in stars, organisms, and societies.

A second difference is that the amount of detail that students are expected to retain is considerably less than in traditional science, mathematics, and technology courses. Ideas and thinking skills are emphasized at the expense of specialized vocabulary and memorized procedures. The sets of ideas that are chosen not only make some satisfying sense at a simple level but also provide a lasting foundation for learning more. Details are treated as a means of enhancing, not guaranteeing, students' understanding of a general idea. The council believes, for example, that basic scientific literacy implies knowing that the chief function of living cells is assembling protein molecules according to instructions coded in DNA molecules, but that it does not imply knowing such terms as "ribosome" or "deoxyribonucleic acid."

The national council's recommendations cover four general categories: The Scientific Endeavor, Scientific Views of the World, Perspectives on Science, and Scientific Habits of Mind. The content forms a common core of learning, emphasizing the ideas and skills that have the greatest scientific and educational significance.

Phase II involves teams of educators from school districts and scientists transforming <u>Science for All</u>

Americans into several alternative curriculum models for the use of school districts and states. During this phase, the project is also developing blueprints for reform related to the education of teachers, materials and technologies for teaching, testing, the organization of schooling, educational policies, and educational research. While engaged in creating these new resources, Project 2061 is trying to significantly enlarge the nations's pool of experts in school science curriculum reform and is continuing its effort to publicize the need for nationwide scientific literacy.

Phase III will be a widespread collaborative effort, lasting a decade or longer, in which many groups active in educational reform will use the resources of Phases I and II to move the nation toward scientific literacy. Strategies for implementing the reform of education in science, mathematics, and technology in the nation's schools will be developed by those who have a stake in the effectiveness of the schools and who will take into account the history, economics, and politics of change.

Scope, Sequence, and Coordination (S, S and C)

This project, organized and coordinated by the National Science Teachers Association, is designed to provide science experiences for all students throughout the secondary school grades and to enhance learning and achievement by (1) spacing learning of scientific disciplines over longer periods of time; (2) sequencing the curriculum from concrete-descriptive science experiences to more abstract-theoretical concepts; (3) reducing the number of topics covered; and (4) providing more school time for science.

The program will replace the current secondary school "layer-cake" curriculum of separate, unrelated courses used by most schools with a curriculum that includes course work related to biology, chemistry, physics, earth/space science and other disciplines each year from grades 7-12. Emphasis will begin with descriptive, phenomenological hands-on experiences in grades 7 and 8, move to empirical, semiabstract experiences in grades 9 and 10, and then to theoretical, abstract experiences in grades 11 and 12. The project also emphasizes coordination of content between disciplines for each school year and careful articulation of content from grade to grade. Some models for this program describe units and courses in which the content for the various disciplines is integrated.

Emphasis of the curriculum may be based on any of several organizational approaches, including distinct subjects taught with coordination, integrated science, unified science, science/technology/society (STS), or others. Content can be based on Project 2061 recommendations, STS topics, conceptual frameworks, or discipline structures.

The project is designed as a research and development effort to produce alternative materials to implement the reform effort. The project also is planning to work with commercial publishers to produce materials for widespread implementation.

Elementary School Science Education Framework (National Center for Improving Science Education)

The National Center for Improving Science Education has produced several publications designed to develop effective science education programs for elementary school children. Getting Started in Science: A Blueprint for Elementary School Science Education (1989) identifies five goals for elementary school science education. They are:

1. To develop children's innate curiosity about the world;

2. To broaden their procedural and thinking skills for investigating the world, solving problems, and making decisions;

3. Tc increase their knowledge of the natural world;

4. To develop children's understanding of the nature of science and technology;

5. To develop children's understanding of the limits and possibilities of science and technology.

The curriculum framework emphasizes themes of organization, cause and effect, systems, scale, model, change, structure and function, continuous and discontinuous properties, and diversity. Topics are to be taught so they provide a direct relationship to the real world. Hands-on activities are emphasized and visual, auditory, and written information sources are to be used to help students develop knowledge, skills, and attitudes with a personally and socially meaningful context.

State Frameworks and Curriculum Guides

Over 40 states have developed curriculum guides and/or state frameworks to influence the local school curricula and instruction. States with detailed frameworks include California, New York, Michigan, Georgia, Wisconsin, and Oregon.

Recent state guides and frameworks have helped to influence local curriculum development, activities of publishers, test developers, and regional and national curriculum development projects.

As this publication goes to press, more than 20 states are reviewing and modifying guidelines and frameworks based on recommendations included in various reports. Some of the proposed changes provide a substantially different vision for precollege science education when compared to current programs.

Curriculum Development Project Frameworks

Some curriculum development projects have developed frameworks for their programs.

Curriculum Framework for Contemporary Elementary School Science and Health (BSCS)

This project (BSCS, 1989) designed a curriculum and instruction framework for an elementary school science and health program for grades 1-6 that is consistent with current trends and needs. It also attempts to integrate technology into elementary school science and health because technology can help to improve learning and technology is deemed worthy of study. The framework includes both curricular and instructional models developed from analyses of the literature, recommendations from individuals, and direct research and experience.

The following passage is the goal statement of the proposed curriculum (BSCS, 1989).

> Children should learn about science, technology, and health as they need to understand and use them in their daily life and as future citizens. Education in the elementary years should sustain children's natural curiosity, allow children to explore their environments, improve the children's explanations for their world, help the children to develop an understanding and use of technology, and contribute to the informed choices children must make in their personal and social lives.

Several assumptions about students were the basis for the design of new curricula. These assumptions include the following: students have motivation; students have developmental stages and tasks that influence learning; students have different styles of learning; and students have explanations, attitudes, skills and sensibilities about the world.

The curriculum framework has several characteristics:

1. The curriculum is based on developmental stages and tasks of students;

2. Activities within the curriculum focus on the students' lives and their world;

3. A student's personal and social context is used to promote healthy behaviors and to develop scientific, technologic, and health concepts and processes; and

4. Activities within the curriculum contribute to learning the basics of reading, writing, and mathematics.

A scope and sequence was developed to describe the structure of the curriculum for every grade level. An instructional model was developed to provide the educational means to achieve designated goals through teaching strategies within the scope and sequence.

Each grade level has three types of units: introductory, core, and integrated. The purpose of the introductory unit is to engage students in the year's study. If the unit engages the students, then the students will direct their interest, enthusiasm, and motivation toward the study of science, technology, and health. The concepts, processes, and skills of the introductory units are those of the core units, and as such, introductory units serve as advance organizers for the core units and serve as a preliminary integration of the concepts. Introductory units also establish such classroom routines as cooperative learning, use of equipment, procedures for hands-on activities, and use of technologies.

Four strands are emphasized each year: (1) science (stuff), (2) technology (things), (3) health (me), and (4) integration for science, technology and health. Content selected is consistent with content identified by Project 2061.

Other Current Curriculum Development Projects

The National Science Foundation is supporting several projects, mostly at the elementary and middle school levels. Included are "Improving Urban Elementary Science" for grades K-6, "Full Option Science System (FOSS)" for grades 3-6 and "The Life Lab Science Program." Each of these projects has guidelines and a framework related to their developmental activities.

The NSF Triad program development effort requires that publishers be included in these development efforts. This requirement should help to overcome a common problem in many development efforts; instructional materials are not produced to help schools implement frameworks. Because publishers have been directly associated with these projects from the beginning, there is a greater probability of having materials available that relate to the project framework.

Goals and Content Statements of Associations and Commissions

Science education and science organizations and commissions have been leaders in producing statements to guide science education curriculum development and instruction. AAAS's Project 2061 and NSTA's Scope, Sequence, and Coordination Project (S, S and C) have both involved most of the major national organizations related to science in their activities. They also have involved organizations related to general education.

In addition to these projects, several organizations including the American Chemical Society, the American Association of Physics Teachers, the National Biology Teachers Association, and the American Geological Institute have been involved in producing other reports identifying what to include in K-12 science education.

The National Association for Science, Technology and Society has been actively working to achieve the conceptualization frameworks for science/technology/society STS (education) and guidelines for curricula, instructional materials, instruction, and evaluation for implementation of the guidelines by schools. These ideas have been developed in publications by Robert Yager, Rustum Roy, Rodger Bybee, Paul de Hurd and others. NSTA was involved in Search for Excellence in Science Education. Criteria were established for selecting programs related to:
(1) program goals; (2) characteristics of the curriculum, instruction, and evaluation; (3) teachers; (4) administrators; (5) community; and (6) students. Programs for chemistry, biology, physics, earth science, elementary school science, STS and environmental education were reviewed and selected as examples of programs implementing the desired criteria.

Trends and Issues

Trends

1. There is a growing consensus that several guidelines should characterize major curricular and program development efforts in K-12 science education. Curriculum and programs ought to:

   a. be consistent with the nature of science, knowledge, processes, organization, and values;

   b. be consistent with the intellectual, social, emotional, and physical development of the learner;

   c. be consistent with research on learning, curriculum, and instruction;

   d. provide for the development of knowledge, skills, and attitudes for life-long learning;

   e. provide interdisciplinary experiences related to current and future life needs for solving personal and social problems;

   f. provide appropriate content, materials, and experiences for <u>all</u> students;

   g. provide an articulated and comprehensive K-12 program;

   h. provide experiences that stress the development of creative and critical thinking, problem solving, and decision-making skills;

   i. provide experiences that emphasize major integrating concepts and principles;

   j. provide experiences that stress the application of knowledge and skills to practical and theoretical problems;

   k. provide experiences that emphasize attitudes and values;

   l. provide emphasis on content and activities that are consistent with the developmental levels of students;

   m. provide emphasis on content and activities that considers a wide range of student abilities, interests, and goals to give all students opportunities to succeed with science and to find applications for their learning;

n. provide emphasis on content and experiences with a high probability of being used outside of school;

o. provide instructional materials that are congruent with the goals and objectives of the curriculum;

p. stress evaluation that is congruent with goals, objectives, and instruction; and

q. provide staff development to assure effective implementation and improvement of the program or curriculum.

2. All guideline and framework teams agreed that there are problems with the content of the current science curriculum and that it should be changed.

3. At the current time, there is lack of agreement on appropriate content for precollege science education and what the emphasis should be.

4. All guideline and framework teams agreed that there should be changes in experiences provided for students in schools. Recommended changes included using a variety of instruction techniques including hands-on activities. Some frameworks, notably BSCS, emphasized the substantial use of technology in instruction.

5. All guideline and framework teams agreed that instructional materials and evaluation procedures consistent with their goals and objectives were needed.

6. All guideline and framework teams indicated there was a need to inform and influence school personnel regarding desired changes and what needed to be done to complement desired changes. The new frameworks represent a major change from those used in most schools.

<u>Issues</u>

1. Should there be a national curriculum?

2. Should states have different curricula?

3. Are these the frameworks that will be most useful for current and future science education? What

science knowledge skills, attitudes and values should all students have and be able to use?

4. Are the frameworks consistent with current research?

5. What content and what experiences should be emphasized at each grade level?

6. Why have frameworks from previous reform efforts had relatively little long-term impact on science curriculum and instruction?

7. Can schools be expected to change their curricula to emphasize these frameworks if assessment instruments are not aligned with these frameworks?

8. What is the relationship of these frameworks for science education to frameworks developed for other content areas such as social studies/social science, mathematics, and language arts?

9. What reforms are required to enable schools and teachers to provide a learning environment to accomplish the goals of the frameworks?

10. How can the frameworks be translated into school curricula, instructional materials, instructional practices, and evaluation procedures?

11. How will the various publics become aware of needed reform and participate in the reform activities?

IV. RESEARCH RELATED TO LEARNING, CURRICULUM, INSTRUCTIONAL MATERIALS, AND INSTRUCTION

Research on science education continues to extend our knowledge of learning, the curriculum, instructional materials, and instruction. Some curriculum development efforts and course improvement projects are attempting to incorporate some of these findings into their work. In other cases, curriculum development and instructional improvement projects are proceeding with little evidence that they are incorporating recent research findings into their planning, products and implementation.

There has been increasing awareness of the need to develop an understanding of the ecology of science learning to help develop effective science curricula, instructional materials, and instruction. Such an ecology of learning needs to establish understandings of the interactions of the student, teacher, curriculum, instructional materials, classroom including instruction, school, home, community and higher education.

Linn noted in 1986 that research during the past decade had developed (1) a growing consensus about the nature of the learner; (2) a new view of the curriculum; (3) a new view of teaching; and (4) exploiting of the new technologies. Research on these themes has continued and is building a knowledge base for use by the field and is identifying additional research that needs to be conducted.

There are continuing concerns regarding (1) the generalizability of research data; (2) the low impact of available research data on curriculum, instructional materials, and instruction in the past; and (3) communicating new research data to interested people in a timely way and in forms so that it can be used.

Research on Learning

Research on learning has been increasing and provides suggestions for improving curriculum, instructional materials, and instruction. New goals for science education, new technology, and research on various aspects of science education and other areas of education have resulted in the identification of new agendas for research on learning related to science education.

Several aspects of learning have been emphasized in recent research and others have been identified as needed. These are briefly considered in this section.

Conceptual Development

Research data related to concept learning have been building. There is increasing agreement (Linn, 1986) regarding the importance of considering how students construct knowledge for the design of curriculum materials and for the instructional process. Prior knowledge is extremely important in an individual's learning process. Most information is learned by connecting it with existing knowledge. Concepts are usually learned most effectively when they are taught in a variety of contexts and are used in a variety of ways.

Constructing new knowledge also requires reasoning skills to be able to process information being learned and to be able to use the information that has been learned.

Knowledge and Alternative Conceptions

Students come to school with previously learned ideas regarding many concepts and topics in the science curriculum. In addition, they are continually exposed to ideas outside of school. Some of these experiences develop alternative conceptions related to science. These beliefs can interfere with learning and need to be identified so that instructional materials and instruction can focus on them to help students learn more effectively. It is important to help students improve their cognitive learning by providing them with materials, learning experiences, and thinking skills that help them process information for learning and use.

A substantial amount of research has been completed in recent years that provides useful ideas for curriculum design, instructional materials development, and instruction (Linn, 1986; Koballa, et. al. 1989; Staver, et. al., 1988; and Baker, in press).

The research indicates the importance of specific content knowledge to a student's learning and the ability to solve problems.

The research also provides suggestions on the order for teaching content (concrete to abstract; familiar to unfamiliar; in larger chunks; related to themes; and with reasoning skills required for processing information) and instructional procedures that help students develop conceptual knowledge.

Reasoning and Problem Solving

Research on reasoning for both the processing of information for learning and for the use of information continues to be an area of a substantial amount of activity. The influence of reasoning on learning is becoming better described. The interactions of reasoning and types of knowledge being learned are also being better described. The role of reasoning in using knowledge is being explored. Research is providing useful information for the design of instructional materials and instruction.

The research that is being produced and synthesized indicates the importance of both content and specific reasoning skills. Students learn concepts more effectively in most contexts when they possess reasoning skills related to the knowledge being learned. They also can generally use reasoning skills more effectively when they have learned reasoning skills with appropriate content.

Research on reasoning and problem solving is clarifying specific reasoning such as combinatorial, hypo-deductive, proportional, analogical and patterns of problem solving.

Procedural Knowledge

Research related to science education has indicated that many aspects of procedural knowledge (process skills) related to science can be taught successfully (ANDERSON, et. al., 1988). Procedural knowledge requires conceptual knowledge, however, to be able to be used effectively in problem solving (Linn, 1986). Procedural knowledge therefore appears to be most effective when it has been learned in context with specific conceptual knowledge. This research provides useful information for constructing instructional materials and guiding some instruction related to specific content.

Metacognition

Research on metacognition related to learning in science continues to be a topic of research. Data indicate metacognition skills are helpful in learning and using science and are seldom taught. Research continues to explore effective ways in which metacognition can be used to enhance learning.

Spaced Learning and Development and Reuse of Knowledge and Skills

Research on spaced learning and development and reuse of knowledge and skills (Dempster, 1988) have been found to be effective for helping to increase learning. This knowledge has implications for the design of curricula, instructional materials, and instruction. While the amount of research in school settings is limited, the NSTA Scope, Sequence and Coordination project is emphasizing the applications of those ideas in its work.

Attitudes toward Science

Research continues to identify the importance of students' attitudes toward science and science courses and their success in science courses and enrollment in science classes when enrollments are elective. Pivotal times appear to be: (1) early elementary grades; (2) late elementary school/middle school years; and (3) required and elective courses in secondary schools.

Use of Conceptual Information and Skills

Analyses of recent science learning indicate that many students do not do well on application problems. National Assessment of Educational Progress (Lapointe et. al., 1989; Jacobson and Doran, 1988) and other data have indicated that this has been a continual problem. It is apparent from other research that students can be taught to see the importance of science concepts and how to apply their knowledge and skills. Students need to have experiences in using information to effectively retain and construct structures for use of information. They need to use and reuse information and skills frequently in a variety of situations to be able to retain important information and skills and to be able to use these skills in a variety of contexts.

Research Related to Curriculum

Recent research indicates that the science education curriculum needs to be modified to help learners achieve desired results. Four aspects of the curriculum (emphasis, placement, treatment of topics and integration) have been the subjects of a substantial amount of discussion and debate and some research.

Emphasis

Analyses of goals, objectives, content and experiences for K-12 science education (Harms, et. al.,1981; AAAS, 1989; Aldridge, 1989; Jacobson and Doran, 1988; Miller, June, 1986; Weiss, 1987; Miller, Jon, 1990; and the National Center for Improving Science Education, 1989) indicate substantial differences between recommendations for K-12 programs and recent and current curricula, instructional materials and instruction. How science programs should provide different emphases has been delineated by several people and groups including Harms, et. al (1981), AAAS (1989) and Aldridge (1989).

Placement of Science Content

Research on learning has been providing clues on the order and placement of content in the curriculum. Characteristics of concepts and skills such as concrete-abstract, familiar-unfamiliar, reasoning skills involved, relationship to other concepts, and relevancy affect the way and the order in which content should be presented.

Treatment of Topics

Research has also been helping to indicate more effective ways of teaching topics to improve both learning and use of knowledge. Among the practices that have been found to make a difference are using hierarchies, spaced learning, focusing on fewer items with more depth, relating knowledge to themes, chunking knowledge, integrating content from various disciplines, learning knowledge in a variety of contexts and using knowledge learned in meaningful contexts.

Time

Research has indicated that several time variables relate to increased learning and achievement. These include emphasis (time) devoted to learning the content, engaged time, recency of instruction, and courses completed. Research is continuing on exploring the impact of how time is used and its relationship to learning of specific concepts and skills.

Background Knowledge and Skills

Increased emphasis should be given to mathematics, language arts, reading and science in the elementary school grades. The importance of establishing a good foundation during the early elementary school years has been consistently shown to be important for further learning (Anderson, et. al., 1988; Wittrock, et. al., 1986). Students who fall more than one and a half years behind grade level during the elementary school years often are not able to maintain effective learning at higher grade levels (Wittrock, et. al., 1986; Howe and Kasten, 1990) in science or mathematics. Elementary school experiences are important for establishing understanding of science concepts and developing needed skills for further learning.

Increased emphasis should be given to building an understanding of basic concepts, problem solving and higher thinking skills. Data from several studies (NAEP, 1988; Jacobson and Doran, 1988; Lapointe, et. al., 1989; and Applebee, 1989 and others) indicated many U.S. students at the upper elementary level and secondary level do not have desired understandings of concepts, problem solving ability, and ability to use higher- order learning skills.

Attitude toward Science

Increased emphasis should also be given to modifications of the curriculum that will help to improve student attitudes. Data (Anderson, et. al, 1982; NSF, 1989; and NAEP, 1988) have indicated students in upper elementary years and middle school years become less interested in science as an area for future study and a possible career emphasis. This is particularly evident for Black and Hispanic students.

Instructional Materials and Delivery of Instruction

Research and development related to instructional materials and delivery of instruction has increased during the past four years. This work has not made an impact on a large number of classes because much of the work initiated recently is in a developmental state.

Current Practice

Instruction in most science classes continues to be textbook and lecture oriented. While some schools are using different materials and practices, the number of schools making substantial changes remains small. Most schools have computers, but relatively few schools have integrated this technology into their curricula; fewer schools have modified their curricula so that the use of technology is a planned part of their program for grades K-12. Relatively few schools have also modified their programs to make use of new technologies such as video discs, interactive video discs, or distance learning.

Instructional Material Research and Development

Research continues to be done on existing materials and developing new materials. Among the topics of research are stated and implied goals, alignment with curricula and tests, content organization, structure, readability, misconceptions in the materials, writing style, visual materials, activities included, and packaging.

Efforts are being made to modify print materials based on research knowledge from both education and the sciences. The NSF sponsored "Triad" projects link publishers with scientists and educators. The AAAS 2061 and the NSTA S, S and C projects also involve people with research knowledge from both the sciences and education.

Researchers at Michigan State University have been developing materials after interviewing students to determine the students' alternative explanations and ways to modify materials to teach concepts more effectively.

Use of Technology to Improve Learning

Research indicates that technology can provide ways of improving learning through creative modifications of curricula, instructional materials, and instruction. Some of the recent research findings and potentials for the use of technology are highlighted in this section.

Use of Calculators in Science Instruction

Calculators are used in science classes, but very little research has been done on their use in these settings. A few studies have been done related to solving problems in chemistry and physics; data indicate the calculators are helpful in enabling students to solve problems faster, solve more problems and solve some problems that would be difficult to solve without their use.

Computers and Instruction

Computers have been found to have mixed success in improving science achievement. More recent studies are more positive than earlier studies, probably due to improved software and knowledge of more effective as well as less effective ways to use computers.

Data indicate many students enjoy using computers. They enjoy being actively engaged; they can make mistakes without being embarrassed; they are in control with many programs; they are kept on task and motivated; and they often receive immediate feedback on what they have done.

Computers have been used for instruction in several ways. Computers have been found to be successful in science for activities requiring drill and practice. Computer-assisted instruction (CAI) has been investigated as a way of improving instruction and learning of science for many years. While data are mixed on its use (Bangert-Downs, et.al., 1985), as more effective materials are developed and as CAI is applied to purposes for which it has been found to be effective, CAI has provided better achievement in a shorter period of time and/or developed better understanding (computer tutors, computer graphics).

Computers have also been used successfully for managing instruction (Computer-Managed Instruction), for simulations, to assist in solving problems, to develop models, to obtain information from databases, for microcomputer based laboratories, and for networking. Computers have also been used successfully as a part of integrated learning systems.

Integrated learning systems have been developed. Several offer a variety of materials for science education. Data indicate that materials have been effective in improving learning for several science education objectives. Materials are available from companies including Computer Networking Specialists, Inc., MECC, New Century Education Corp., Roach Org, Inc, Wasatech Education Systems, and WICAT Education.

Distance Education

Distance education is being used to provide a variety of resources for precollege education for several purposes. One of the major uses in the United States has been to assist rural schools by providing courses to augment the school curriculum. A second common use has been to provide enrichment experiences to a variety of schools for their more able learners. A third and newer use in science has been conferencing and sharing research information.

Research indicates distance education has been effective for adult learners in a variety of settings (Moore, 1989). Data related to its use and effectiveness for K-12 education has been less conclusive, although reports indicate it offers many opportunities for schools and students that they cannot obtain in traditional ways. A number of systems are available to schools, but most have limited materials and courses at this time.

Audiovisual Technology

Several technologies have been developed to the point that they are being used in classrooms for instruction, though not on a wide-scale basis. Videodiscs, interactive videodiscs, CD ROM, and interactive TV are among the technologies being used and which hold promise for modification of curriculum and instruction.

The research database related to these technologies is being developed and some results have been published (U.S. Congress, 1989; Jostens Learning Corporation, 1989). Suggestions for improving the materials and making them more effective for instructional purposes have been made, though the extent to which the data can be generalized is not clear at this time. Many improvements are being made from analysis of use by producers, rather using formal research and evaluation procedures.

Instruction and Classroom Climate

During the past 10 years, there has been an increased amount of research related to instruction and learning. In addition, many of these studies have been reviewed and synthesized to provide strategies for the application of research to practice. From this research, patterns of instruction used, how learning occurs and can be facilitated, and variables related to learning and achievement have continued to be identified. Research on learning, instruction, and technology has been developing a new view of teaching (Linn, 1986).

Knowledge regarding how students learn and construct their knowledge and how they use their knowledge indicates the importance to the teacher of both subject matter and skills. New technology permits instructional experiences that could not be offered before. The importance of having a teacher who understands the content and skills they are trying to teach has also been thrust into sharper focus; it is difficult to teach concepts and skills if you do not understand the concepts and skills.

Analyses of current instruction, however, indicate that most teachers use more traditional instruction and are not making use of many instructional procedures that have been found to improve science learning.

Variables Related to Increased Achievement

Among the strategies and variables that have been related to increased achievement are: (a) homework assignments; (b) low absenteeism; (c) corrective measures for errors in learning; (d) high teacher expectations; (e) teachers' confidence that they can help students; (f) academic time; (g) engaged time; (h) classroom organization; (i) feedback on learning; (l) congruence of instructional materials, instruction, and evaluation; (m) wait time; (n) cooperative learning techniques; (o) procedures to help students construct knowledge and to eliminate misconceptions; (p) preinstructional strategies (set-induction, focusing, advanced organizers); (q) questioning strategies;

(r) hands-on activities; (s) emphasis on concrete materials and examples; (t) focus on specific reasoning skills and concepts; and (u) mastery learning approaches.

While most of the recent and current instructional improvement efforts have been at the elementary school level, secondary school students and programs have been included in recent research.

There is a developing consensus that recent research efforts provide knowledge about teaching and learning that can make a substantial impact on instruction. Some of the information is currently being applied; further work is needed to translate more of the information so that it can be used in practice and to determine effective combinations of variables to use.

Assessment and Evaluation

Data continue to indicate that many national and statewide evaluation programs and instruments do not measure the major current goals and objectives of science education. They also differ markedly from proposed goals and objectives of newer frameworks.

Research data indicate that evaluation of programs and instruments needs to be congruent with the curriculum, instructional materials, and instruction in order that a curriculum program succeed. Teachers tend to emphasize what is being tested and students focus their time and attention on what is being tested.

Nearly all reports concerned with the topic of evaluation call for different evaluation instruments.

Teacher Characteristics, Behaviors and Preparation

Trends and issues related to this topic are outside the scope of this publication. However, research data clearly indicate that effective teachers are a requirement for any curriculum to succeed.

Recent research information related to learning and instruction helps to identify teacher competencies needed for effective student learning. Preservice and inservice teacher education programs need to assess how current knowledge should influence programs to prepare effective teachers.

School Practices and Organization

Several school building practices are related to effective science programs and higher student achievement. Among these variables are school leadership, articulation of instructional goals, time allocation for programs, class size, supervision practices, school and staff expectations, teacher stability, staff development activities, and resources (time, materials, personnel).

Learning is enhanced when the building as a unit is focused on providing a setting for maximizing learning.

Community/Home Variables

Research continues to show significant relationships between achievement/attitudes and community/home variables, particularly socioeconomic levels of the home and expectations of the home and community.

These data support the development of programs that involve the home and the community in school activities. The data also support the development of out-of-school programs for youth.

Trends and Issues

Trends

1. A growing body of literature has increased consensus that research is changing how the learner is viewed and learning occurs.

2. There is a growing body of literature and increasing consensus that research on learning and curriculum indicates that the curriculum should be modified to aid and improve learning.

3. There is a growing body of literature and increasing consensus that research on learning, instructional materials, and instruction indicates that instructional materials and instruction should be modified to aid and improve learning.

4. There is a growing body of literature and increasing consensus that research on learning, curriculum, instructional materials, instruction, and evaluation indicates that evaluation instruments and procedures need to be modified to aid and improve learning, instruction, and programs.

5. Research continues to provide suggestions on ways to improve curriculum, instructional materials, and instruction.

6. Recent research has helped identify areas needing more research and new agendas for research.

7. Research data indicate teacher knowledge and beliefs regarding science, science curriculum, instruction, instructional materials, and evaluation influence how teachers teach.

8. Research data continue to indicate that early school learning and achievement have a strong relationship to later learning in science.

9. Research data continue to indicate that school practices relate to science learning and achievement. Specific school practices have been found to relate both.

10. Research data continue to indicate that community/home variables relate to science achievement and learning. Specific variables have been found that relate to both.

11. Research continues to describe curricula, instructional materials, and instruction used in K-12 classrooms for science education. These data indicate that recent research has not made a major impact in many schools on any of the three.

12. The use of technology is slowly increasing in schools. Few schools have made major modifications in curriculum, instructional materials, and instruction based on use of technology.

<u>Issues</u>

1. Can the science education community be encouraged to direct more of its research toward areas identified as new agendas and areas in need of research?

2. How can procedures be established to support studies and replication of studies to permit greater generalization of data?

3. What can be done to have research make a greater impact on curriculum instructional materials, and instruction?

4. What can be done to help synthesize completed research more effectively?

5. What can be done to identify the implications of synthesized research for curriculum, instructional materials, and instruction?

6. What can be done to communicate research results, synthesized research results, and implications of research to appropriate audiences in timely and effective formats?

7. Should regulations and incentives be used to encourage those involved in the design and production of curriculum and instructional materials to use research results in developing their products.

8. Should regulations and incentives be used to encourage those involved in selecting materials and providing instruction to use research results in their work?

V. DEVELOPMENT AND IMPLEMENTATION OF CURRICULA AND INSTRUCTIONAL MATERIALS FOR PRECOLLEGE SCIENCE

This section presents trends and issues related to recent and current activities designed to develop and implement curricula and instructional materials. Activities include (1) revising and strengthening science curricula and developing instructional materials, (2) modifying instruction, (3) revising high school graduation and college entrance requirements, (4) devising programs to recruit and to hold minority and female students, (5) expanding the curriculum and extracurricular programs to include contests and competitions, (6) developing programs for science outside of school hours, (7) developing special schools that include an emphasis on science, (8) accountability and evaluation, and (9) staff development.

Revising and Strengthening Science Curricula and Producing Instructional Materials

There has been substantial activity during the past three years to address concerns related to the precollege science curriculum.

State Curriculum Guides

There has been continued activity by states to develop or revise curriculum guides for science. About 30 states have recommended guides and over 20 have required guides; some have both. Only a few states do not have any form of guide for science.

Guides vary in detail, but there is a trend to include more recommendations on instructional objectives, instruction, and assessment based on research. There also is a current effort to review guides against Project 2061 recommendations. Some states have begun to consider guides against the NSTA S, S and C recommendations. Efforts are underway to modify some guides to reflect these recommendations or to issue analyses that indicate how some of the recommendations can be incorporated into their curricula.

Materials to Support Comprehensive Curricular Frameworks

Several groups developing comprehensive curricular frameworks for science grades K-12, 1-6, and 7-12 were described in Section III.

Project 2061 has developed a framework and is working with schools and scientists to modify curricula for specific schools.

The Scope, Sequence and Coordination (S, S, and C) project is developing centers to work with schools to develop curricula based on S, S, and C guidelines. S, S, and C is also working with several states to develop curricular frameworks based on S, S, and C guidelines. Some states, California, for example, are using S, S, and C guidelines and incorporating content from Project 2061. Some curriculum development efforts are also emphasizing S, S, and C guidelines and emphasizing Science/Technology/Society content.

Several of the S, S, and C projects are developing units for the secondary school level. Availability will be through the National Science Teachers Association and/or commercial publishers.

BSCS is working with several groups to integrate science, technology and health in an elementary school curriculum called New Designs. This program incorporates educational computing into the curriculum and instruction as a fundamental component. Materials will be published by a commercial publisher.

Because curriculum development and materials development require considerable time, much of the materials being developed for national framework projects are not available for general school use at this time.

Other Selected Curriculum Development Activities

Elementary/Middle School Materials

The National Science Foundation has recently sponsored one middle school and seven elementary "Triad" projects (partnerships made up of publishers, scientists and science educators, and schools) to produce high-caliber innovative curricula. Projects funded include the following:

1. Elementary School Science and Health Materials (K-6). Funded by NSF and Kendall/Hunt Publishing Co., this program emphasizes personal/social goals, problem solving, decision making, and technology in relation to science knowledge and procedures.

2. Improving Urban Elementary Science: A Collaborative Approach (K-6). Funded by NSF and Sunburst Communications, Inc., this partnership is developing a program using the natural world as an experimental starting point to enhance students'

critical thinking and problem-solving skills.

3. The Life Lab Science Program: Development of a Comprehensive Experimental Elementary Science Curriculum (K-6). Funded by NSF and Addison-Wesley Publishing Co., this comprehensive garden-based program aims to show students, through a variety of hands-on experiences, the connections between science and daily life.

4. The Science Connection (1-6). Funded by NSF and Silver Burdett and Ginn, this program supplements existing basal science texts with materials to enhance science instruction and improve students' abilities to think critically.

5. Super Science: A Mass Media Program. This program, funded by NSF and Scholastic, Inc., introduces two classroom magazines (for grades 1-3 and for grades 4-6) accompanied by computer disk resources whose activities blend science with math, reading, and social studies.

6. Full Option Science System (3-6). Funded by NSF and Ohaus Scale Corporation, this project is producing multisensory laboratory-based activities for the elementary classroom.

7. National Geographic Kids Network Project (4-6). Funded by NSF and the National Geographic Society, this project's series of units can be used with existing classroom materials. Using telecommunications to share information across the country, students investigate issues of scientific, social, and geographic importance.

8. Interactive Middle-Grades Science (6-8). Funded by NSF and Houghton Mifflin, this project is developing a multimedia system of instruction/classroom management/student evaluation that addresses problems of science, technology, and society.

Michigan State University personnel (Berkheimer, et. al., 1988) are involved in developing curriculum materials for elementary school science using different procedures than those normally used. Michigan State University researchers identify alternative concepts students have and then use this information to develop instructional procedures. Research data indicate modules developed with their procedures have been more effective than some traditional materials.

There are also a variety of materials being developed by commercial publishers, producers of computer software, audiovisual producers, and integrated system companies. Local schools are producing or adapting materials to supplement current curricula; Eisenhower and Title II funds from the U.S. Department of Education have been used by several schools for this purpose.

There has been a definite increase in the development and modification of curriculum and instructional materials during the past several years. Most of the curricula and materials produced to date would need to be modified or adapted to fit the Project 2061 recommendations. Most curricula and materials would also have to be modified or adapted to fit the NSTA S, S and C recommendations and models. Most of the materials produced recently have been for a few units for separate grade levels or for one year and have not provided sufficient materials designed for an articulated program for several years; fitting pieces together in an effective and meaningful way becomes difficult for many schools.

Secondary School Materials

Several secondary school curriculum development and material development projects have also been completed or are underway in addition to those cited earlier. The majority of the larger projects are by publishers, producers of computer software, and producers of audiovisual materials. There are also projects at (1) special schools for science and mathematics including North Carolina and Texas; (2) local schools; and (3) collaborative groups of schools. Funding for these has come from a variety of sources including publishers, government (federal and state), private foundations, business partnerships, and local schools.

Comments relative to elementary/middle school materials are also true of these. Most of the materials have not been designed and developed to produce materials for an articulated program for grades 7-12 or even for several grades. Most of the materials would also need to be modified or adapted to meet the recommendations of Project 2061 NSTA's S, S and C, and literature recommendations on curricula and instructional materials.

It is difficult to implement recommendations of groups such as Project 2061, NSTA's S, S and C, and others without mater'als designed to facilitate learning according to the recommended programs. It is especially difficult to construct learning if materials do not exist for multiple years.

Developing Materials and Programs that Use Electronic Media

There has been a substantial amount of development activity to produce software including supplemental software, software for microcomputers that include substantial portions of a semester or more, interactive videodiscs, courses for integrated learning systems, software and materials for microcomputer based laboratories, databases for educational use, and materials for networking. There have also been some excellent materials developed for television at both the elementary and secondary school levels.

There has also been development and experimentation with distance learning programs, including STAR School programs. Schools in several states have been involved in these activities. Use has not been high, but advantages and disadvantages of distance learning are being learned and use is increasing. Rural areas have generally been more involved in the use of distance education for science education.

Television has received the most use, and microcomputer use is steadily increasing. Problems frequently reported related to the use of technology include costs of equipment and materials (when available), teacher knowledge related to the technology and time to plan and use the technology, quality of materials, and "fit" between the school curriculum and the materials available.

Modifying Instruction

There has been substantial effort to assist teachers in learning about and using instructional materials and procedures that can be used to assist students in learning and becoming more interested in science.

The Eisenhower Act of the U.S. Department of Education has supported inservice activities in every state. The National Science Foundation, private foundations, business and industry and states have supported inservice programs. The Regional Educational Laboratories, supported by the U.S. Department of Education, have also been involved in assisting schools to modify instruction.

Professional associations have been active in working with schools and in presenting ideas in publications. The NSTA, AAPT, and ACS have been noteworthy in their efforts at the national level. State affiliates and state representatives of these groups have also been actively involved in working directly with schools.

Reports suggest that changes are occurring where emphases is given to instructional improvement and when resources and time are provided to make needed changes.

Revising High School Graduation and College Entrance Requirements

There has been a significant increase in science requirements for high school graduation by state governments during the past several years. From 1980 to 1987, 46 states introduced or increased graduation requirements.

There also has been a trend for colleges and universities to increase the number of science courses or years of science required for admission. These requirements have caused many local school districts to raise the required number of science courses for graduation in an academic or college-bound program.

Devising Programs to Recruit and to Hold Minority and Female Students

There has been increased effort and support to develop and maintain programs to interest minorities and females in science, help them succeed in science, and encourage them to continue in science. Over 30 states have programs designed for these purposes.

Local schools, associations, colleges and universities, businesses, and foundations are also developing programs related to minority and female students. Intervention programs, if replicated with care and given stable funding, can make a difference. For example, the Southeastern Consortium for Minorities in Engineering (SECME), sponsored by universities and corporations, coordinates intervention programs across the Southeast United States to reach over 200 schools, 27 universities, 45 corporations, and approximately 15,000 minority students a year.

Expanding the Curriculum and Extracurricular Programs to Include Contests and Competitions

Contests and competitions are receiving increased emphasis at the international, national, state, regional, and local levels. The number of programs, the number of schools participating, and the number of students participating have generally been increasing. Recognition given to winners, especially those for international and national competition, has also been emphasized more in recent years.

As interest in these contests and competitions has increased, there has also been interest in school, community, and student variables related to schools that are highly successful in these competitions.

Developing Programs for Science Outside of School Ho rs

Special programs for students are being offered more frequently outside of school hours for able students, minorities, females and students who need time to improve their knowledge and skills.

Summer programs are being offered by many school districts, colleges and universities, and states; at the current time more than 20 states offer summer programs. The formats for these programs vary from several days to as much as six weeks. Sites also vary; some are held at a local school, but many are offered at colleges and universities, camps, research facilities, science and technology centers, and museums. Funding for summer programs has also been increasing with federal, state foundation, and business support for many. The integration of science, computers, technology, and mathematics has been emphasized by many such programs.

After-school programs and Saturday programs are also being used to provide more time for science and to provide more extensive experiences than the school can offer onsite. Many of these programs use local colleges and universities, research laboratories, museums, science and technology centers, and local industries as sites for programs.

Special programs to help students who need more time to learn fundamental knowledge and skills have also been developed. While most of these programs focus on what the student needs to learn, some try to develop increased interest in science by showing applications of science and/or involving students in science activities not usually encountered in the school.

Developing Special Schools that include an Emphasis on Science

Special schools have been developed by several states and cities for science and technology. There are at least 15 states supporting or helping to support states/schools that focus on science. Several cities have magnet schools that focus on science and technology that are supported in part by state funds, but not considered state schools.

While the number of state and locally supported schools for science and technology is increasing, the number is not increasing at a ·apid rate.

Accountability and Evaluation

There is a strong consensus in the recent literature that changes are needed in testing and evaluation procedures to reflect desired goals. National Assessment of Educational Progress planners, IEA planners, centers such as the Center for Improving Science Education, BSCS, and state guide developers are examples of groups working on modifying evaluation instruments and procedures.

Changes being designed and implemented include emphasis, types of items, procedures for collecting data and use of data. There is an emphasis on major concepts, higher-order questions, hands-on activities, and use of technology in answering questions.

Aligning assessment with the curriculum, instructional materials, and instruction is being emphasized, but data suggest this practice is not frequently followed. Use of assessment data to aid learning and to improve instruction, therefore, is frequently difficult and often suspect.

Staff Development

Although staff development is not the focus of this publication, it has been identified as a major need in reform activities. It has received and is receiving strong attention and financial support. The amount of inservice education has increased dramatically with federal support from the Eisenhower Act and other programs from the U.S. Department of Education, National Science Foundation, U.S. Department of Energy, and NASA. In addition, states, local schools, foundations, and businesses are also providing support.

Identified teacher needs include those related to beliefs, methodology, and current knowledge of content, materials, and instruction.

Many reports indicate that previous reform efforts have failed to a large extent because teachers did not believe they needed to change instruction; they were not aware of curricular materials or instructional procedures; or they did not understand them; therefore, they would not implement them properly and/or lacked sufficient knowledge and/or skill to instruct the class effectively.

Resources for Supporting Development, Dissemination, and Implementation

Science education has been receiving increased support for curriculum development, instructional material development, and implementation. Major increases have come from federal funds (NSF, U.S. Department of Education, and others), private foundations, and business and industry. Additional increases in support have been provided by some states.

The federal government has been supporting some dissemination activities through the U.S. Department of Education (Eisenhower Act, FIRST, NDN, ERIC), the National Science Foundation, and other agencies. States have also been providing resources for dissemination. In addition, new federal legislation is being considered to provide for additional dissemination of information regarding curriculum and instruction.

Professional associations have continued to focus on dissemination of information through conferences, meetings, and publications. Associations have also been involved in establishing networks, including electronic networks, to share information with potential users.

Data were not available to indicate whether local funds have been increased beyond the rate of inflation, though articles and reports continue to identify resources for the purchase of equipment, materials, nd supplies as a problem; these items are usually obtained with local funds.

There has been a steadily increasing number of partnerships involving business, industry and schools. In many localities these arrangements have provided funding, materials, personnel, and other resources for assisting in the improvement of K-12 science education.

Trends and Issues

Trends

1. Some curricula and instructional materials for K-12 science are being developed or revised to reflect increased knowledge of how students learn science, provide more emphasis of major concepts, more emphasis on higher-order learning, make more use of technology, provide for more

active learning, and provide for more applications.

2. Work is being done to improve assessment of learning and to develop indicators of effective programs at local, state, and national levels.

3. Very few science curricula have articulated programs that include grades 1-12.

4. Use of technology for science instruction is increasing, but slowly.

5. Funding support and opportunities for inservice education for teachers of science has steadily increased during the past several years.

6. There has been continued development of programs for minorities and women to interest them in science and to provide assistance.

7. The percentage of schools participating in contests and competitions is increasing.

8. The percentage of schools and agencies offering programs outside of school hours is increasing.

9. The number of special schools that emphasize science has been slowly increasing.

10. Support for curriculum development has been increasing for several years. The amount of support remains low for the tasks identified as needed.

11. Support for dissemination and implementation has increased in recent years, but the amount of support on a per school basis is very low.

Issues

1. How can effective instructional materials be developed to implement curricular recommendations?

2. How can more effective instructional procedures be implemented in the schools?

3. How can more effective assessment procedures be developed?

4. How can more effective assessment procedures be implemented in the schools?

5. How can the use of technology be increased to improve the teaching and learning of science?

6. How can needed improvements in science education be financed?

7. Can significant and important changes be made in K-12 science without substantial restructuring of schools?

8. How can federal, state, and local policies that <u>encourage</u> reform be enacted?

9. How can federal, state, and local policies that <u>sustain</u> learning improvement activities be enacted?

10. How can reform activities in science education be coordinated?

11. How can reform activities in science education be coordinated with other school reform efforts?

VI. SUMMARY AND RECOMMENDATIONS FOR THE REFORM OF K-12 SCIENCE CURRICULUM, INSTRUCTIONAL MATERIALS, AND INSTRUCTION

The preceding sections presented information and trends related to: (1) conditions creating a demand for change; (2) the status of science education in elementary and secondary schools; (3) curricular frameworks for precollege science education; (4) research related to learning, curriculum and instruction, instructional materials and instruction; and (5) current activities to create desired changes in curriculum, instructional materials and instruction. The recent literature also identified recommendations for reform of K-12 science education. A selection of recommendations suggested are identified in this section.

Conditions Creating a Demand for Change

Summary

Reports document at least seven conditions requiring a demand for major changes in science education K-12. Included among those most frequently cited in the literature are: (1) changes in the world society and the United States; (2) changes in international business, marketing, and competitiveness; (3) changes in the role of technology and the use of technology in schools and in society; (4) changes in the need for scientific knowledge and skills for everyday living and for jobs; (5) changes in science and how it is used; (6) research on curriculum learning, instructional materials, and instruction; and (7) a discrepancy between changes desired and current school programs and student achievement.

Several of these conditions demand changes in other areas of the school program. While science reform can be addressed specifically, it should also be considered as part of a total needed reform.

Recommendations for Reform

1. Changing conditions should each be analyzed to explicate what needs to be done in science education to take advantage of new knowledge, provide needed content and experiences, and correct discrepancies between desired achievement levels and current achievement levels.

2. The information obtained from this analysis should be used to analyze the comprehensiveness of current frameworks for science education for the development

of new frameworks for science education.

3. A mechanism should be established to determine progress related to meeting these needs as well as opportunities and changes in conditions that present new needs and opportunities.

What is the Status of Science Curriculum, Instructional Materials and Instruction in Elementary and Secondary Schools?

Summary

Analyses of student science achievement in U.S. schools indicate that American students are not learning several concepts and skills as well as desired. Analyses also indicate that U.S. students are not achieving as well on many desired concepts and skills as students in several other industrialized countries.

Additional data indicate that the science curriculum, instructional materials, and instruction do not introduce new concepts as early as those in some other 6-36 countries nor provide concepts in as much depth and with opportunities for spaced learning. Data also indicate that some of the desired concepts and skills do not receive sufficient emphasis in U.S. curricula, instructional materials, and instruction and that the time U.S. students are involved in science instruction is less than the time students in several other industrialized countries are involved in instruction.

Recent data indicate that most U.S. schools follow traditional instructional patterns, provide little hands-on instruction, and make relatively little use of technology. Very few schools have curricula especially designed to capitalize on the useful features of hands-on instruction and new technology throughout their programs.

Recommendations for Reform

1. Achievement data identified for four NAEP studies indicate very little change for all students at all grade levels tested. Major systemic reforms are needed in science education to markedly improve learning and achievement.

2. Data indicate that early schooling in science and mathematics has a strong relationship to later achievement, particularly for low income and minority students. Any major reform needs to provide a special

focus on the first three years of schooling to prepare all children adequately for continued learning. Mathematics, reading, and language skills are among the most essential learnings to be emphasized.

3. Assessment tests need to be developed that reflect current goals and objectives. Schools that emphasize and achieve these goals and objectives should be identified to aid continued improvement of all schools.

4. Current practices in most schools indicate that past reforms have not had a major impact on instruction and classroom practices. Barriers to change need to be addressed so that current reform efforts are more effective to producing changes in instruction and improvements in learning.

Curricular Frameworks: Goals, Content, and Experiences for Precollege Science Education

Summary

The science education community, with strong leadership from the AAAS and the NSTA and with substantial support from the federal and state governments and private foundations, has developed curricular frameworks for science education that provide guidelines for the development of science programs. The AAAS Project 2061 activities have identified suggested content and instructional and evaluation patterns. The NSTA S, S and C Project has identified desirable characteristics for a curriculum and for instruction.

Other groups such as the National Center for Improving Science Education and BSCS have also been active in developing their own guides and frameworks and also adapting guides and frameworks to fit the recommendations of Project 2061.

Curriculum development programs that have included textbook publishers have also developed frameworks. Most of these have been for elementary or middle school grades.

While some of these development projects are working on plans for implementing reform ideas, others are not. Some projects are producing instructional materials, evaluation instruments, and recommendations for instruction, while others are not.

Recommendations for Reform

1. There is a need to involve all major stakeholders in reviewing the frameworks, establishing the need for the frameworks, identifying what the frameworks will accomplish, and identifying alternative ways they can be implemented.

2. There is a need to develop and to test materials, instructional procedures, and evaluation procedures in a variety of sites.

3. Effective prototype materials need to be shared widely with state and local school personnel so that they can be adopted and adapted.

4. Effective communication procedures need to be established for all personnel interested in continuing developments in science education. The communication procedures should use both on-line and print techniques, be widely publicized, and permit multiple pathways for information exchange.

Research Related to Learning, Curriculum, Instructional Materials, Instruction, Evaluation, and School/Community Variables

Summary

Section four presents selected research on K-12 science education. Research information is available to provide for significant improvement of cognitive, affective, and psychomotor science learning and achievement. Suggestions are available for modifying the curriculum, instructional materials, instruction, evaluation, and school and community activities to be more consistent with research on learning and achievement.

Some of the results of this research are being used by curriculum developers, developers of evaluation instruments, and school personnel working to improve community, school, and classroom activities. However, relatively few instructional material developers are making substantial use of this knowledge and relatively few schools are making substantial use of available research information.

Recent research and new technologies have also established the need for new research agendas related to precollege science education. As we learn more about the learner, curricula, instructional materials, instruction, and school/community variables that affect learning, there are needs and opportunities for research that can continue

to help the education community to understand learning and to improve educational processes.

Recommendations for Reform

1. Support needs to be provided and mechanisms developed to make better use of available research knowledge for the improvement of K-12 curricula, instructional materials, instruction, and teacher education.

2. Support needs to be provided and mechanisms developed to replicate previous studies that indicate promising practices for the improvement of science education to determine the extent to which the fundings can be generalized. These replications will probably achieve better results if conducted on an organized basis as opposed to an unorganized approach.

3. Support needs to be provided for research related to new goals and frameworks for science education. Included are higher-order learning, assessment, curriculum materials, effects of technology on science instruction and learning, efforts of revised forms of curricula for grades 9-12, policy-related issues (outcomes/inputs; regulations, etc.), teacher knowledge, and prototype programs for accomplishing specific goals with specific groups of students.

4. Support needs to be provided for research and development to develop new learning systems.

5. Expand and support ways of sharing information related to research on K-12 science education. Current mechanisms do not reach enough people who should be informed and information frequently is not in the most useful form for specific groups of people (policy makers, curriculum developers, researchers, etc.). These activities, if done right, require substantial staff, cost a considerable amount of money, and probably can be most effectively developed and sustained with federal support.

Current Activities to Create Desired Changes in Curriculum, Instructional Materials, and Instruction

Summary

Efforts to develop new science curricula and produce instructional materials have accelerated during the past three years. Activities of the NSF, Project 2061, S, S and C, BSCS and others are developing procedures and materials to change curricula, instructional materials, and instruction. In addition, some states, local schools and groups of schools are working to change curricula and instructional materials. Many of these efforts involve partnerships of schools, curriculum developers, publishers, and business and industry.

Use of technology in instruction is slowly increasing and materials being developed for science instruction used in conjunction with technology are also increasing.

Efforts to change instructional procedures through inservice education have increased during the past several years--largely due to an infusion of funds from federal and state governments, foundations, and business and industry.

Programs for attracting and assisting minorities and females in science and engineering have continued, as have programs sponsoring science contests and competition and activities outside school hours.

Special schools for science and technology continue to operate and a few new ones are being developed.

The need for changes in assessment and the uses of assessment has been recognized, and several organizations, agencies, and groups are working to modify current practices.

Finally, support for development, dissemination, and implementation has been increasing, but the amount available per school is very small.

Recommendations for Reform

1. Several of the frameworks being developed for K-12 science education lack details and ideas relating to implementation. Alternative articulate curricula need to be developed for clusters of grades (ideally K-12) to assist schools that want to implement the frameworks. Recent research on cognitive learning argues against fragmented, unrelated instruction; it also argues for strong programs in the early grades to aid concept development, development and use of reasoning skills, and development positive attitudes.

2. Barriers to change identified in a variety of publications need to be addressed and corrected. A substantial amount of knowledge has been developed on the change process during the past 30 years. This information should be considered in developing solutions to real and perceived barriers.

3. States should work with local school districts to help them align their goals, curricula, instructional materials, instruction, and evaluation/assessment. Work to align all aspects of the science program can be a powerful force in reforming science education.

4. States and local schools (especially large urban, county, and parish districts) need to communicate what instructional materials they want to publish. Collaborative efforts between states and local schools should be established with publishers for the production of materials. Many states and metropolitan areas have more students than do the countries with whom the U.S. is compared in international studies.

   States and large school districts need to exert more leadership in assuring quality curricula, instructional materials, and instruction. Reports indicate school districts often will adopt frameworks, especially if useful materials are available to support frameworks.

5. The use of technology in instruction is increasing slowly. Major barriers include lack of teacher knowledge related to effective use of technology such as computers and the lack of highly effective materials to use with the technology. Efforts should be provided to assist teachers and to provide more useful materials.

6. The impact of various special programs (contests, after-hours programs, out-of-school programs, special schools, programs for minorities, etc.) should be analyzed. Models that are effective for specific outcomes should be documented and information shared with schools. Models that are less effective for specific outcomes should also be identified, and information should be shared with schools.

7. Support systems for schools interested in modifying their curricula and instruction need to be developed. Analyses of the new frameworks and many ofthe newer materials indicate that effective use in the schools will probably require major modification of classroom and school procedures.

8. Efforts to change assessment need to be accelerated. There is substantial evidence that tests are one of the many variables influencing curricula and instructional materials.

9. Staff development, both at the preservice and inservice levels, needs to focus on a vision of science education and curricula, materials, instruction, and evaluation that will accomplish the desired goals. Teachers' belief systems influence what they consider, what they use, and what they do.

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