DOCUMENT RESUME

ED 281 910 UD 025 448

AUTHOR	Howe, Robert W.; And Others
TITLE	Persistent Problems in Precollege Mathematics, Science, and Environmental Education: Issues, Trends, and Recommendations.
INSTITUTION	ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, Ohio.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE	Jan 87
CONTRACT	NIE-P-85-0008
NOTE	18p.; In: Trends and Issues in Education, 1986 (see UD 025 435).
PUB TYPE	Information Analyses - ERIC Information Analysis Products (071)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Academic Achievement; Educational Improvement; Educational Trends; Elementary Secondary Education; *Environmental Education; *Instructional Effectiveness; Instructional Materials; *Mathematics Education; *Science Education; Teacher Recruitment; Time Factors (Learning)
IDENTIFIERS	Educational Issues; Excellence in Education

ABSTRACT

This report considers the following issues, trends, and recent activities in science, mathematics, and environmental education: (1) inadequate achievement in knowledge, concepts, skills, and processes pertaining to these subjects; (2) curricula which do not provide the content needed for current and future academic and personal needs, do not reflect existing knowledge of learning and instruction, are not considered relevant by many students, and do not encourage the use of instructional materials besides textbooks; (3) lack of time devoted to problem-solving in mathematics and science; (4) inadequate emphasis on environmental education in terms of curriculum development, materials, and time devoted to the topic; (5) recent research describing effective instructional techniques; and (6) recruitment and retention of qualified teachers. In addition, recommendations for needed action are provided, as is a list of references. (PS)

Persistent Problems in Precollege Mathematics, Science, and Environmental Education: Issues, Trends, and Recommendations

By

Robert W. Howe, Patricia E. Blosser, Marilyn N. Suydam,
Stanley L. Helgeson, and John F. Disinger

Chapter 12 of
Trends and Issues in Education, 1986

Erwin Flaxman
General Editor

Prepared by
Council of ERIC Directors
Educational Resources Information Center (ERIC)
Office of Educational Research and Improvement
U. S. Department of Education
Washington, D. C. 20208

January 1987

PERSISTENT PROBLEMS IN PRECOLLEGE MATHEMATICS, SCIENCE, AND ENVIRONMENTAL EDUCATION: ISSUES, TRENDS, AND RECOMMENDATIONS

Robert W. Howe, Patricia E. Blosser, Marilyn N. Suydam,
Stanley L. Helgeson, and John F. Disinger
ERIC Clearinghouse for Science, Mathematics,
and Environmental Education,
Ohio State University, Columbus, OH

We are currently living in a world and a nation that have changed substantially during the past 30 years. Major changes have taken place in our society and culture, and the societies and cultures of many other nations of the world.

The events of the past 30 years have created what has been called an emerging post-industrial society, an information age, and a period of historic economic transition. The conditions creating these changes are based, in part, on the amount of information available, new technologies for processing and using knowledge, and a marked decrease in time between scientific discoveries and their widespread application.

There have also been substantial changes in the scientific enterprise. The boundaries between science and technology have become less distinct; in many cases, science and technology have become integrated systems for research and development. Scientific research has become increasingly problem-oriented, rather than discipline-oriented. Much of the research at the cutting edge of science involves people from several disciplines and has led to the development of new sciences. Societies are increasingly looking for benefits from science in addition to basic knowledge; people are concerned with the improvement of the quality of life and the reduction of human problems and suffering.

Science is also having an increased impact on society. As societies place increased emphasis on the use of science and technology for improving the quality of life, important values and ethics emerge that relate to decision-making regarding how science and technology should be used in attempts to improve the quality of life. As scientific knowledge is transformed into technological applications at an increasingly rapid rate, impacts on the agricultural, industrial, and service sectors of the world's economy are extensive. The social and economic changes now set off from these impacts are profound and far-reaching.

Needs have also been changing related to mathematics. With major changes in business, industry, and technology, different mathematical knowledge and skills are needed. Much of the mathematics frequently taught in the elementary school can be done with calculators and computers. New technologies and problems to be solved now require mathematical knowledge and mathematical skills that are not included or not emphasized in the precollege curriculum.

Problems related to the environment and the natural resource base continue to confront society. Air, water, and land pollution problems are featured daily in our newspapers, magazines, and television programming. Use and management of resources continue to be major national and international issues. Many personal and societal decisions are being made and need to be made related to these topics; substantial information is required by citizens if these decisions are to be made wisely.

Our current understanding of how children learn, how curriculum and instructional materials can be organized, and how teachers can provide more effective instruction makes us capable of producing important reforms of educational programs and practices. Implementation of this information should modify our choice of content for the curriculum, the design and structure of instructional materials, the use of instructional materials, instructional strategies used by teachers, learning strategies used by children, and evaluation purposes and procedures. We have the opportunity to make progress in developing solutions to several persistent, continuing problems in science, mathematics, and environmental education.

This chapter considers issues, trends, and recent activities in science, mathematics, and environmental education related to (a) achievement, (b) curriculum, enrollments, and instructional materials, (c) instruction, and (d) teacher quality, supply, and demand. In addition, recommendations for needed action are identified.

Achievement

Data obtained from a variety of studies by individuals, states, national groups, and international groups indicate that students are not learning knowledge, concepts, skills, and processes as well as desired. In addition, international comparisons indicate that a large majority of American students do not score well on achievement tests in science and mathematics compared to students in other countries. While there have been some increases in test scores in recent years, the gains have not been large. Scores for able students (especially those planning to go into science and mathematics careers) have remained more stable. Some indicators have shown these students to be making gains. Achievement scores for blacks and minorities have shown improvement, especially in lower grades, but still lag behind those for white students. Scores for females are lower than for males by the time they graduate from high school.

Data have indicated an upward trend in mathematics achievement during the 1980s, but results are mixed, both on topics tested and achievement by students from different geographical areas. Test data indicate that students generally score well on computation, especially whole numbers, and low on problem-solving, applications, and problems involving more complex mathematical skills. Many students also do not master the use of fractions and decimals and do not understand concepts related to measurement, especially metrics and geometry.

Tests administered by various states and professional groups do not show student achievement patterns or achievement gains that are similar across geographical areas. Achievement varies substantially from state to state and within many states. Progress being made to improve achievement also shows substantial variation.

These student achievement patterns on mathematical topics and across geographical areas are not new. Data analyzed for the past 30 years indicate similar patterns. Reasons for these trends, some effective intervention approaches, and recommendations for future action are presented in following sections.

Science achievement scores show mixed results, depending on the instruments analyzed. In general, elementary level students have shown slight gains in recent tests, while most secondary school students have shown declines, though students planning to major in science or mathematics have generally shown stable scores or slight increases. Student scores in science have consistently indicated lowest achievement on items related to physical sciences, problem-solving, and applications. Some tests have shown recent declines on earth science and integrated science topics.

Comparisons of student science achievement patterns across geographical areas show differences, as in mathematics. While fewer data are available for making comparisons in science, achievement materials analyzed indicate substantial differences from state to state and within most states. Progress being made to improve achievement also shows substantial variation.

As in mathmatics, these achievement patterns are not new. Science achievement patterns have indicated similar results for many years. Reasons for these trends, some effective intervention approaches, and recommendations for future action are presented in following sections.

Students frequently develop misconceptions related to science and mathematics that are not corrected by current instruction and instructional materials. The same errors tend to be made at several different grade levels and, in some cases, persist through high school. These misconceptions frequently interfere with later learning and with effective problem-solving. Research is being conducted to identify some key misconceptions and to design intervention strategies; some useful suggestions for modification of curriculum, instructional materials, and instruction are now available.

Many students become less positive in their attitudes and interests toward science and mathematics as they progress through school; by grade eight students frequently rate science and mathematics among their least favorite school subjects. Elementary and high school students also frequently rate the two subject areas among the most difficult subjects they study. Academic success generally correlates significantly with positive attitudes and interests. Instruction that leads to student success, hands-on activity or "doing" activities, and working with other students and is conducted by an energetic, interested teacher is frequently associated with students who have more positive attitudes and interests toward mathematics and science.

While the data are limited, it has been found that student knowledge and understanding of many concepts related to the environment are not strong. Items included on National Assessment of Education Progress (NAEP) tests and other tests indicate that students do not understand concepts such as those related to pollution, biological cycles, population issues, and natural resources (including energy scurces). The low knowledge level that many students possess makes it difficult for them as students (and later as adults) to make rational personal and societal decisions regarding the environment.

A number of variables that relate to low and high achievement in all three areas have been identified through research and will be considered. Some schools are using interventions including these variables; in other cases more research, development, and implementation activities are needed to move the research into practice.

Some caution needs to be used in analyzing test data. Comparisons of tests and textbooks/curricula indicate a substantial discrepancy between many of the textbooks/curricula and the content and the emphases of many of the tests. Comparisons of tests with classroom instruction also indicate substantial differences between what occurs in the classroom and the content and emphases of many of the tests. The tests are not measuring all that has been learned; hence, the contents of tests used for evaluation and research should be examined to be certain that what is being measured is the knowledge, skills, attitudes, and values that are believed to be important.

Curriculum, Instructional Materials, and Enrollments

Among the strongest variables related to student achievement are: (a) amount of focused time and use of time for desired learning; and (b) the extent to which the desired learning is emphasized in different years. Therefore, the curriculum, instructional materials, and student enrollment in courses should be a major focus of efforts to improve science, mathematics, and environmental learning.

Curriculum and Instructional Materials

Reports from inside and outside the education community agree that substantial changes should be made in both the curriculum and instructional materials to reflect current and future personal and societal needs, new technologies, and recent research on learning.

There is general consensus that the curricula in all three areas, but especially in the fields of mathematics and science, do not reflect our current society and societal needs, do not provide the content needed for current and future academic and personal needs, do not reflect our knowledge of learning and instruction, and are not considered relevant by many students.

Since a textbook is the primary tool in instruction for most mathematics, science, and environmental education teachers, there is substantial concern that materials be available to implement needed curriculum changes. Recommendations are unlikely to be implemented without appropriate instructional materials for the teachers to use.

Data indicate that materials with different content, content organization, skill emphasis, psychological order, and format have different impacts on student achievement.

Mathematics--Curriculum

Many people continue to be concerned about the mismatch between the way arithmetic is taught in school and the way it is used in real life, the over-emphasis of time on skills that are now learned best (for example, computation and recognition), lack of application and problem-solving experiences, lack of time for topics and experiences that people believe should be in the curriculum, lack of use of cognitive research for determining order and procedures for teaching concepts and skills, and a fragmented secondary school curriculum. The National Council of Teachers of Mathematics and other groups have taken the initiative to change these conditions.

The need to redevelop curricula to reflect the changing needs of society and to incorporate the new techniques and processes made possible by computers and calculators has led to a number of wide-scale funded projects, as well as to state and local efforts. The development of numeracy--an understanding of mathematics and mathematical procedures--seems imperative, and the need for restructuring of traditional secondary school courses is evident. Such courses should include but not be limited to algebra, geometry, and general mathematics, so that technology is used as a vehicle of instruction rather than an end in itself. Modifying the content of elementary school mathematics programs is also a goal of curriculum development efforts. Decreasing the emphasis on computation while increasing the emphasis on estimation, probability and statistics, geometry, and other vital but neglected topics is being stressed. Developing understanding as well as skill with fractions, decimals, and other number ideas is similarly needed. Increased emphasis is being given to the need for more stress on problem-solving and applications in specific situations to improve problem-solving and knowledge use and transfer. Research information on cognitive learning can provide suggestions for ways to organize and to structure the curriculum.

Mathematics--Instructional Materials

"Instructional" materials in mathematics conjures up the image of a vast array of material devices and other articles to aid in teaching mathematics: blocks, the abacus, Cuisenaire rods, chip trading games, spinners, as well as calculators and computers. Reality, however, is something else; textbooks and tests predominate. The use of nontextbook materials is the highest in first grade and the percentage of use generally decreases as the grade level increases.

The evidence on the value of the use of manipulative materials is very clear: they have a high probability of increasing achievement and appear to be essential in providing a firm foundation for developing mathematical ideas. Many studies provide at least partial support for the use of materials in stages progressing from concrete to pictorial to abstract or to symbolic. The use of either or both physical and pictorial aids results in significantly higher achievement than when only symbols are used. Correct use of objects and materials is also important.

There is little doubt that textbooks and tests shape the curriculum. However, analyses of textbooks and tests indicate substantial diversity among textbooks, among tests, and between textbooks and tests. Emphasis on concepts and skills recommended by various associations and groups differs substantially among texts and tests.

Use of calculators and computers is increasing, but the number of classrooms in which either or both are being used an adequate amount of time is low. Data from more than 100 studies involving the use of calculators strongly supports their use for saving class time and student time, increasing achievement, and improving student attitudes toward mathematics and the student's self-concept with respect to mathematics. Computers can also provide instructional benefits; mathematics teachers need to incorporate computer applications more meaningfully into mathematics instruction.

Mathematics--Time

Among the strongest variables related to mathematics achievement are (a) amount of time devoted to the objectives of instruction, (b) number of courses in mathematics a student has completed, (c) use of the concept or skill in applications and problem-solving, and (d) recency of the instruction related to the objective.

Providing more time in the elementary school curriculum can probably be accomplished best by a reduction in paper and pencil computation and the increased use of hand-held calculators. This would also have an impact on the sequence of instruction, approaches used in teaching, and content selected for inclusion in the curriculum.

Time devoted to application and problem-solving experiences is substantially less than what is required to develop effective skills and understandings. Time can most likely be obtained at lower grade levels by using tools such as the calculator and by modification of what is taught. Time can be gained at the secondary level by using calculators and computers and modifying the curriculum. Modifying the curriculum for secondary school students should include developing courses for all students and developing special courses for college-bound students planning to major in engineering, mathematics, and the natural sciences. Data indicate that the average graduate from high school has completed between two and three years of high school mathematics (out of four years). While about 70% of students pursuing academic programs have completed three years of mathematics, less than 30% of the general and vocational students have completed three years. These data suggest that requiring more courses without modifying the curriculum will not provide appropriate mathematics experiences for either group of students.

Science--Curriculum

While there is substantial debate regarding the desired curriculum for science, consensus is developing that the science curriculum needs to be modified to (a) include more emphasis on problem-solving, decision-making, applications, technology, societal issues, and the physical sciences; (b) reflect current understanding of the nature of the learner and of learning; (c) increase the amount of time available for instruction; (d) provide appropriate experiences and courses for all students; (e) increase the use of technology; and (f) reduce the breadth of content to allow for more depth.

The current curriculum in most schools does not reflect these directions; however, activities at national, state, and local levels are evident. The American Association for the Advancement of Science, the National Science Teachers Association, several state departments of education, and the National Science Foundation are among groups leading in efforts to modify the curriculum.

Major efforts to date have focused on increasing the emphasis on technology and societal issues in the curriculum, increasing the amount of science required in the curriculum for college-bound students and some other students, increasing the emphasis on problem-solving and applications, and increasing the use of technology. Several state and local curricula reflect these emphases, and others are following.

There have been conferences to consider more fundamental changes in the curriculum. Recommendations have been made by various groups, and work is underway to study and to implement some of the proposed changes.

Science--Instructional Materials

Science instruction can involve many materials, as in mathematics; however, reality in science is the same as in mathematics--textbooks and tests predominate. The use of nontextbook materials appears to be the highest in lower elementary grades and upper secondary grades.

The evidence for the value of the use of manipulative materials in science is similar to the findings reported for mathematics. Activity-oriented programs that use manipulative material are generally more successful in promoting student achievement in the use of science process skills, creativity, and higher cognitive skills. Proper/effective use of materials is also important in science. Cognitive learning research has provided a number of suggestions for the order of using materials and the ways of using materials. Most practice clearly does not reflect available research.

Textbooks and tests become the curriculum for most schools. As in mathematics, there is substantial diversity among textbooks, among tests, and between textbooks and tests. Emphases on concepts, skills, attitudes, and values recommended by various professional associations and groups differ among texts and tests. The impact of cognitive learning research on science textbooks has been minimal. Articulation between textbooks, even within some series, is not strong; articulation between secondary science courses frequently does not exist. While there have been recent conferences involving various stakeholders on ways to correct these and other concerns related to textbooks and courses, major efforts are in the discussion, planning, and pilot stages. Recent and current research regarding use of materials has the potential for guiding substantial change in the development and use of materials.

Science--Time

Among the strong variables related to science achievement are (a) amount of emphasis devoted to the objectives of instruction, (b) the number of courses in science a student has completed, and (c) recency of the instruction related to the objective.

Providing more time for science in the lower elementary school curriculum can probably be accomplished best by integrating science experiences with other activities such as writing, reading, art, physical education, and health. In the upper elementary grades and many middle schools, more time would clearly help to achieve desired objectives; modification of the curriculum, however, could make the curriculum more efficient and effective. Data indicate that about 50% of graduating high school students take no science after grade 10 and no physical science after grade 9. Increased time is being obtained by requiring students to take more science courses; these requirements raise the question of what science students should take. Modification of the secondary school curriculum is clearly needed if these courses are to be appropriate.

Some time can be gained by use of technology and simulations in science laboratory acitivities to allow more time for problem-solving and decision-making experiences; research consistently shows that most science instruction is not successful in achieving these goals at desired levels.

Environment--Curriculum

Environmental education has found no discrete place in the curricula of most schools, but elements of it (ranging from classical "nature study" through outdoor education and traditional conservation education) continue to exist in many localities. Current emphases in environmental education focus on interactions between and among science, society, technology, and environment, calling for input from the natural sciences, the social sciences, and the humanities, but these are not yet generally implemented. The major difficulty continues to be finding a place for interdisciplinary instruction within school organizational patterns which are in large part along disciplinary lines, at least in departmentalized secondary schools. In the case of self-contained elementary classrooms, a lack of teacher education in the interrelationships among science, society, technology, and environment, and in the pertinent basic content areas themselves, remains a practical problem.

Environment--Instructional Materials

There are few if any textbooks, at any grade level, which deal with science-technology-society-environment interrelationships, as well as a corresponding deficiency in numbers of texts in the more traditional aspects of environmental education--nature study, outdoor education, conservation education. The environmental education community has, however, developed and made available a number of teacher-oriented guides and modular-type instructional materials, with the expectation that they can and will be inserted into existing curricula in many areas, particularly the sciences and social studies, as appropriate. These materials range from traditional areas to the more modern ones. These modular materials are being used for instruction primarily by science and social science teachers. The materials also are being used for curriculum development by science educators who want to increase the amount and focus of material in the curriculum on science-technology-society.

Environment--Time

As implied above, the general pattern for time spent in instruction in environment-related areas is minimal. As a generalization, few schools teach "environment" as a discrete area; such a situation is likely to arise only in the case of the elementary teacher who has a particular interest, or of the secondary teacher (usually of science, less frequently of social studies, and rarely of other disciplines) who has a particular interest and a local opportunity.

However, the inclusion of environmental topics, such as in courses related to science-society-technology, is an expanding area. Many of the societal concerns inherent in science-technology-society considerations are in fact environment-based and/or contingent on environmental considerations. Thus, the growing thrust to emphasize "environment" in such courses is increasingly evident.

Instruction and Classroom Climate

During the past 20 years there has been an increased amount of research related to classroom 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, variables related to increased learning and achievement have been identified.

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; (j) questioning techniques; (k) mastery learning; (l) congruence of instructional materials, instruction, and evaluation; (m) wait time; (n) cooperative learning techniques; and (o) procedures to help students construct knowledge and to eliminate misconceptions.

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.

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

The Effective Schools research provides directions for school building and classroom practices that can help to improve student achievement. Data from over 100 studies and reports indicate that staff who incorporate the recommended practices into their school programs can usually expect to obtain higher student achievement. The extent of the gains appears to be related to (a) the extent to which the recommended practices are implemented; (b) the congruence among the goals, instruction, instructional materials, and evaluation; and (c) the amount and quality of time devoted to the assessed objectives. References to these studies are included in two publications in the "References" on effective/successful schools (Howe & Butts, 1986 and Kyle, 1985) and the publication Research within reach: Science education (Holdzkom & Lutz, 1985).

Meta-analysis studies and other secondary analysis efforts have yielded extremely useful data regarding instructional strategies, the amount of gain obtained by use of a specific strategy or combinations of strategies, and the percentage of studies in which positive gains were obtained by experimental groups. Observations of a large number of mathematics and science classrooms and reviews of research studies indicate that many of these practices are not being used or, if they are being used, they are not being used in effective ways. Effective use of appropriate combinations of these strategies should produce significant achievement gains for most teachers.

Recent research has developed a better understanding of how students construct knowledge and develop or change misconceptions. While this is still an emerging research area, knowledge has been gained that is useful for modifying many current instructional practices. Learners develop conceptual frameworks or models that depend on understanding specific subject matter; if the subject matter is not understood, then the student will likely develop some misconceptions. Research data indicate the importance of teaching to reduce misconceptions at the elementary school level so that students learn reasonably correct concepts and models. Very few schools are doing much to teach students how to learn and to help them avoid misconceptions and correct those that they have.

A change in emphasis and modification of many preservice and inservice programs is clearly needed if schools are to implement the data identified in this section. Most teachers are not aware of current information and procedures to use to implement the instructional approaches.

Teacher Quality, Supply, and Demand

Developing and maintaining a sufficient number of qualified teachers has been another persistent problem.

The amount of science and mathematics course work taken by elementary school teachers has not changed appreciably during the past 25 years; most have had three or fewer courses in science and two courses or fewer in mathematics as undergraduates. Few elementary teachers have taken additional coursework in science or mathematics after graduation. Very few elementary teachers have taken college courses that emphasize environmental problems.

The preservice preparation of most primary grade elementary school teachers is not likely to change substantially in terms of credit courses in science or instructional procedures for teaching science. While preservice programs for these teachers should focus on our current knowledge of instruction and knowledge of science, inservice education programs need to carry the burden of helping primary grade teachers.

Many schools are again looking for science specialists for upper elementary grades and middle schools. Programs have been developed by some institutions to provide for the needs of these teachers and other institutions are in the process of developing such programs. The National Science Foundation plans to support several model programs for the preparation of teachers at the middle school level.

Very few states have had a sufficient number of well prepared chemistry and physics teachers, middle school or junior high science and mathematics teachers, or earth science teachers during the past 20 years. The teacher shortage has usually been in areas of rapid population growth, inner cities, and rural areas, and continues to be primarily in these areas at this time.

Developing and maintaining a supply of qualified teachers has become more severe as other vocations have attracted women, an increasing salary differential has developed between teaching and other careers requiring similar preparation, the work place has been viewed as less than desirable, and teacher status has decreased. Attracting people (both men and women) to the teaching profession and getting teachers who have left the classroom to return has become more difficult.

Among the solutions being proposed and tried in order to retain and to recruit teachers are: (a) increasing all teacher salaries; (b) providing differential pay for teachers in shortage areas (geographic) or content areas (subject); (c) developing merit pay programs; (d) developing career ladder programs; (e) providing modified work schedules for teachers; (f) providing increased recognition for competence in teaching; (g) assigning teachers outside their regular teaching fields to teach mathematics or science; (h) waiving certification requirements for teaching; (i) developing special programs for preparing teachers in shortage areas; (j) developing forgivable loan programs for people who prepare to be teachers and teach in a specific state; (k) improving the working conditions in schools; and (l) improving the image of the teacher in the community.

Articles have been written by proponents of and by detractors from various programs on philosophical as well as perceived or real operational problems. Some relevant research has been reported, but the results of specific efforts are difficult to assess at this time since very few programs have been in operation for a substantial time and, in many cases, combinations of solutions are being used. Data available indicate that few simple solutions will attract a sufficient number of well-prepared teachers. Those states and communities that are having success in reducing teacher shortages and maintaining or increasing the quality of the teaching staff are using several approaches. It is also evident that some solutions such as loans, improved school climate, and teacher recogntion require time before they have an impact on staffing.

These actions to recruit, retain, and reassign people are taking place at the same time that many educators believe our capability of developing more effective teachers has increased. The growing knowledge base regarding useful content knowledge, pedagogical knowledge, and effective instructional skills has again raised questions regarding the kind of education and training a teacher should receive. Efforts are currently underway in several states, colleges and universities, and communities to design preservice and inservice programs that build on existing knowledge.

Preservice and inservice programs need to consider what subject matter, content knowlege, and competence teachers need to have, and not what science courses a teacher should have or the requisite number of hours in science. These programs also need to focus on instruction that is useful for achieving specific objectives and the probable impact of the use of alternative procedures and strategies on pupil achievement and attitudes.

Programs also need to be developed to help prospective teachers and inservice teachers understand how knowledge is constructed by the learner so that they can become better self-learners and can be more effective and efficient in selecting content, designing instruction, and evaluating student learning.

Priorities for Action

If the precollege programs in mathematics, science, and environmental education are to develop students with knowledge, skills, and attitudes that are needed, substantial reform is needed in curriculum, in instructional materials, in teacher education, and in instructional programs. Some needed activities have been identified in previous sections of this chapter.

Most of the major problems identified have been persistent problems in education. Approaches to alleviate these persistent problems will require commitment to long term efforts and willingness to modify past practices in very different ways. There are some activities that deserve priority attention.

Curriculum

There is substantial consensus among a broad public that the curricula in all three areas (science, mathematics, environmental education) has not been well delineated for students' current and future needs. Most current curricula do not reflect the present state of science and mathematics, the "information age," cognitive research on learning and instruction, and the effective use of technology as it relates to the curriculum. Problem-solving, decision-making, and applications are not stressed. Interdisciplinary groups should be established immediately to develop suggested frameworks for consideration by a broader public. These frameworks can provide direction for the other needed activities. Without a good curricular framework, many of the state and local activities will be patches on a worn out tire.

Instructional Materials

Since over 90% of the instruction in the United States in science and mathematics is based on textbooks, modification of instructional materials deserves high priority. Priority should be given to materials for upper elementary grades, middle schools, and courses for senior high school nonscience majors. Reasons for these recommendations are extensive, but a few will be highlighted.

Students begin developing their conceptual understandings, interests, attitudes, values, and skills in the elementary years; many studies have shown students at these age levels are not developing cognitively and achieving as desired. Success for these students is important and materials that will help promote success can be developed. Many students make their decision to take science or mathematics in secondary schools based on their experiences in the upper elementary and middle school years; a large number of students are currently opting not to take these secondary school courses.

Science materials for the nonscience majors are also needed. One of the few widespread reform actions that has been taken in many states has been to increase the number of courses in science or mathematics required for high school graduation or college admission. This action will have little impact on science and mathematics majors; they are already taking the required number of courses. It will have substantial impact on those students going to college who are not majoring in mathematics or science and for those students not going to college. Different courses should be developed for many of these students. Our priorities do not imply that other materials are not needed. Research data, school program development, state regulations, student enrollment patterns, and analyses of existing materials support the strong need for efforts at these priority levels. The National Science Foundation's recent program related to middle schools is beginning action on some of these needs.

Materials developed should reflect the curricular framework established (see curriculum recommendation), be based on available cognitive learning research, be designed to make effective use of available technology (calculators, computers, and so forth), emphasize problem-solving and decision-making, emphasize how to learn, and be activity-oriented.

Teacher Quality and Supply

Action is needed to maintain and to improve the quality of both inservice and preservice teachers. The teacher is usually considered the key to student success. Priority should be given to developing strong inservice programs to provide assistance and instruction directly related to the teachers' instructional responsibilities. Programs should be developed by local schools to meet local needs. State and federal support, however, should be provided on a continuing basis to assure that inservice programs are maintained and to help balance economic differences among communities. Evaluation should be required to identify program impact on students and to improve programs. Developing good inservice programs will have a more immediate effect on improving student achievement, interests, and attitudes than will preservice programs. Inservice programs should also be more efficient and effective than preservice programs since all these teachers are in the schools and teaching; most of them will be in the schools for an additional 7 to 15 years. The future quality of the schools depends to a great extent upon their effectiveness as teachers. Priority should be given to upper elementary and middle schools for inservice activities.

Preservice programs need to be strengthened and recruitment of prospective teachers needs to be expanded for the long-term improvement of pre-college education. Incentives, such as loans that will be cancelled for years of teaching experience, should be established and maintained by all states with teacher shortages. There is evidence that incentives do work if maintained over time.

More competitive teacher salaries are needed to attract people into teaching and to retain teachers in the schools. Improved working conditions are also needed to retain teachers in the schools.

Classroom and School Climate

Research on effective and successful schools indicates substantial improvements in student achievement and teacher morale can be made at reasonable costs by implementing various combinations of school and classroom improvement procedures. These practices should be implemented and considered by other schools when it appears that these procedures will improve the educational program.

Classroom Instruction

Research accumulated over the past several decades provides useful suggestions for ways to change instruction that will generally improve student achievement. Materials should be developed for use with inservice and preservice teachers to show them how to use this information and these procedures in their classes. Inservice programs should then be developed to prepare a cadre of teachers to work with other teachers in trying these procedures.

Impact of Research on Practice

While there are many reasons why research information has not made the desired impact on practice, a major variable is awareness. No practice improvement information and materials can be used if people do not know they exist. Secondly, no practice improvement information and materials will have much impact if they are not in a form that provides sufficient information, materials, and assistance to help school personnel understand the practice. Some programs have been effective in helping schools become aware of information and materials and how to use them. The National Science Foundation programs of the 1960s and early 1970s were effective in getting many schools to become aware of mathematics and science materials and to use them; many of these materials had very positive effects on student achievement, interests, and attitudes. Several U.S. Department of Education programs such as the Educational Resources Information Center (ERIC) and the National Diffusion Network (NDN) have been effective in creating awareness and use of materials. However, these programs have not been sufficiently supported or developed to accomplish the needed tasks. Existing programs should be reviewed, improved, and supported to enable them to assist schools in appropriate ways. Existing school networks need to be used in the effort, and others need to be developed. Programs developed should reflect available technology and research on school improvement.

Federal, State, and Local Commitment to Mathematics, Science, and Environmental Education

Over 100 reports issued during the past five years have indicated there are severe problems and perhaps a "crisis" in pre-college education. Actions taken to date by most people responsible for educational programs do not reflect efforts of magnitude that indicate these persons really believe there are severe problems or that a crisis existed or exists. Leadership is needed at all levels in dealing with the problems that do exist and that have existed for many years. Resolving these problems will take additional resources and a continuing commitment to improvement. Some good activities have been renewed by the National Science Foundation, the U.S. Department of Education, some states, and some local education authorities; these actions, however, are insufficient for the task and do not show long term commitment.

References

Anderson, R. D., et al. (1982, December). Science meta-analysis project for NSF Project No. SED 80-12310. Boulder, CO: University of Colorado, Laboratory for Research in Science and Mathematics Education. (ERIC Document Reproduction Service No. ED 233 476)

Coleman, W. T., & Selby, C. C. (1983). Educating Americans for the 21st century. Washington, DC: National Science Foundation. (ED 233 913)

Committee on Research in Mathematics, Science, and Technology Education. (1985). Mathematics, science, and technology education: A research agenda. Washington, DC: Author.

Gardner, D. P. (1983). A nation at risk. Washington, DC: U. S. Department of Education. (ED 226 006)

Hersch, C. (Ed). (1985). The secondary schools mathematics curriculum. Reston, VA: National Council of Teachers of Mathematics.

Holdzkom, D., & Lutz, P. (Eds.). (1985). Research within reach: Science education. Washington, DC: National Science Teachers Association.

Howe, R. W., & Butts, D. (1986). Effective successful schools and instructional research: Implications for science programs and instruction. Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education, The Ohio State University.

Hurd, P. D. (1986). Issues in linking research to science teaching. (Information Bulletin 1). Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, The Ohio State University.

Iozzi, L. A. (1984). Summary of research in environmental education, 1971-1982. Columbus, OH: ERIC/SMEAC, The Ohio State University.

Kyle, R. M. J. (1985). Reaching for excellence: An effective school sourcebook. Washington, DC: U. S. Government Printing Office. (ED 257 387)

National Science Board. (1985). Science indicators: The 1985 report. Washington, DC: U. S. Government Printing Office.

Raizen, S. A., & Jones, L. (1985). Indicators of precollege education in science and mathematics. Washington, DC: National Academy Press.

Suydam, M. N. (1984). Assessing achievement across the states: Mathematical strengths and weaknesses. Columbus, OH: ERIC/SMEAC, The Ohio State University.

Wittrock, M. C. (Ed.). (1986). Handbook of research on teaching (3rd ed). New York: Macmillan.

Yager, R. E. (1982). What research says to the teacher (Vol. 4). Washington, DC: National Science Teachers Association.