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ABSTRACT

The two science education digests for 1985 contained reports of research related to science curriculum and instruction. This information bulletin has been designed to continue making suggestions for improving education, more specifically education in science classrooms. It focuses on: (1) findings from science education studies (including "Project Synthesis"); (2) findings from reports dealing with excellence in education (such as "A Nation at Risk: The Imperative for Educational Reform"); (3) findings from science education research studies; (4) why there is an impetus for change in science education; (5) information from Canadian science educators, considering steps involved in "deliberative inquiry," seven curricular emphases in science, and issues related to incorporating a science and technology focus into science curricula; and (6) who decides curriculum questions. One generalization offered is that persons interested in improving science education have some positive findings from the meta-analysis research data upon which to build in terms of instructional strategies that lead to increased student learning and other positive outcomes. In addition, science for general education should not be neglected since science instruction should be geared toward both the citizen and the future scientist. Thirty-five references are also included. (JN)

ERIC®
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Information Bulletin No. 3, 1985

IMPROVING SCIENCE EDUCATION

Readers of the digests and information bulletins produced by personnel of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education may remember that the 1984 information bulletin in science education contained information from some of the national reports about the status of education in America. The two science education digests for 1985 contained reports of research related to science curriculum and science instruction. The 1985 science education information bulletin has been designed to continue the theme of suggestions for improving education, more specifically education in science classrooms. It is based, in part, on a 1985 information analysis product (SE 046 340) focused on improving the curriculum in science education. Readers who wish more information than is contained in this information bulletin are encouraged to read the longer publication which is available as a part of the ERIC data base or which may be purchased from the SMEAC Information Reference Center.

Science Education Studies

The National Science Foundation provided incentives for science course improvement projects in the 1950s and 1960s. In the 1970s NSF personnel issued a request for proposals to analyze the impact of these programs. Three status studies were conducted (Helgeson, Blosser, and Howe, 1978; Stake and Easley, et al., 1978; Weiss, 1978). The findings from the literature review (Helgeson, Blosser, Howe, 1978), from the case studies (Stake and Easley et al., 1978), and from the national survey (Weiss, 1978) indicated some things had changed while others remained much the same as they were prior to the NSF activities in science education. Teachers still perceived the same barriers to effective science teaching as they had identified 20 years ago but there was an increase in student-centered and hands-on instruction, as well as far more alterna- for instructional materials. Case study data showed science education being given a low priority in the 11 schools studied, with emphasis on basic skills displacing attention from science. General education aims for science instruction were lacking. Science was taught as what experts had found to be true. The textbook was viewed as both the authority on science knowledge and the guide to learning. While federally-funded curriculum materials were in use in both K-6 and 7-12 grades, the use of textbooks lectures and discussion was more widespread and frequent than was the use of manipulative materials. The use of manipulative materials appeared to increase with increasing grade level. (Those who subscribe to the Piagetian approach to cognitive development may question the emphasis on manipulation with older students who are presumed to have progressed beyond the concrete operational stage. Looking at this finding in a more positive manner, it may indicate an increase in laboratory work in science courses for older students.) Funds were lacking for purchase of equipment and supplies as well as for the individualization of instruction. Not only were science facilities inadequate, teachers lacked adequate planning time - particularly at the elementary school level. Students were described as possessing inadequate reading abilities and lacking interest in science, thus posing problems for science teaching.

The National Science Foundation asked nine professional organizations to analyze the three status studies and produce reactions to their content. These reaction papers were published in *What are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field* (1980). The National Science Teachers Association (NSTA) emphasized the importance of the teacher, taking the position that ". . . ultimately improvement can stem only from the initiatives and efforts of teachers supported and assisted by local administrative and supervisory personnel . . ." (1980:50). NSTA urged that immediate attention be given to elementary school science by the provision of inservice workshops focused both on subject matter and on classroom techniques.

The American Association for the Advancement of Science (AAAS) advocated that serious attention be given to improving the quality of education. The AAAS writers considered the problem of quality to be broader than that of providing up-to-date curricula - it involves the school ethos. They urged the establishment of a commission similar to the 1893 Committee of Ten (which was composed of nationally recognized and respected leaders) to conduct an in-depth examination of the goals and purposes of precollege education.

The National Academy of Sciences Commission on Human Resources provided six recommendations in reaction to the NSF status studies:

1. the establishment of a number of Science and Mathematics Teaching Resource Centers to provide inservice education; construction, maintenance, repair, and distribution of kits of materials for teaching science; expert advice to teachers to help them learn to use instructional materials and techniques and to assist them in solving teaching problems
2. increased support for development and revision of new courses and associated materials
3. support for NSF teacher institutes
4. development of additional science and technology centers such as those now existing in a number of cities
5. increased efforts to encourage and recruit women and minorities for careers in scientific and technological occupations, and
6. local efforts to improve both achievement and pupil assessment (1980:79-80).

The Association for Supervision and Curriculum Development (ASCD) report said that ". . . the studies imply the following needs:

Instructional Materials

1. Continued development of high quality instructional materials, with federal sponsorship if necessary.
2. Procedures for periodically redefining what students should learn.
3. A thorough examination of the processes by which textbooks and teachers; manuals are developed, selected, and used - so that they may be improved.
4. Objective evaluation of instructional materials.

Teacher Education and Support

1. Redefinition of middle management roles to provide more adequate staff development and support for teachers.
2. Mechanisms, such as NSF institutes, to provide for continuing education of teachers.

Knowledge

1. Knowledge about differences in points of view between teachers and other educators.
2. Knowledge about the change process in schools.
3. Knowledge about effects of various practices and programs. (1980:139)

What are the Needs . . .? never achieved the visibility and recognition that the status studies received. A later science education report did capture the attention of the science education community, building on the status studies as part of its data base. That report, *Project Synthesis,* involved an examination of the status studies, data from the reports of the National Assessment of Educational Progress (NAEP) science assessments, current science textbooks, and some other reports on the current situation (1979-1980) in K-12 science. It was published, in 1981, as part of the NSTA series *What Research Says to the Science Teacher, Volume 3* (Harms and Yager, 1981).

Project Synthesis (described in the 1981 ERIC/SMEAC information bulletin) involved five separate focus groups: biology education, physical science education (including earth science), inquiry in school science, elementary school science education, and the interaction of science, technology, and society in the secondary schools. All groups, working independently, conducted a discrepancy analysis: setting forth a desired state of affairs and then describing the actual state of affairs in order to identify the discrepancies between the actual and desired states. Once discrepancies were identified, recommendations for future action were made.

The five groups were bound together by common use of a framework provided by a set of broad goal clusters:

Goal Cluster I–Personal Needs
Science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world.

Goal Cluster II–Societal Issues
Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

Goal Cluster III–Academic Preparation
Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate to their needs.

Goal Cluster IV–Career Education/Awareness
Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests. (1981:7-8)

The participants in Project Synthesis emphasized that the world of the 1980s is much changed from the world of the 1960s. They urged the science education community to rethink the goals of science education.

Other Reports

One of the several reports, to the American public, on education that received much publicity is *A Nation at Risk: The Imperative for Educational Reform* (1983). The 65 pages of this document contain a depressing picture of American education as well as a number of recommendations for change. Prepared by the National Commission on Excellence in Education, the document contains sections related to content, expectations, time and teaching, and recommendations relative to each area. Commission members called for an increase in standards and expectations as reflected in both requirements for graduation from high school as well as in admission to higher education. They urged that all students take at least four years of English, three years of mathematics, three years of science, three years of social studies, and one-half year of computer science. They advocated an increase in the length of the school day as well as in the school year. They did not recommend changes in content beyond revision and updating.

Also in 1983 the National Science Board Commission on Precollege Education in Mathematics, Science and Technology produced *Educating Americans for the 21st Century.* The aim of this group was to so improve education that the achievement of Americans would be the best in the world by 1995. This report included a section entitled "Suggestions for Course Topics and Criteria for Selection" (1983:96-100) in which desired science outcomes were specified for grades K-6, 7-8, and for biology, chemistry, and physics. These desired outcomes of science instruction involve understanding and appreciation of the external and internal biological and physical environments. Learning is to be a life-long process.

The Nation Responds, published in 1984, contains information about recent efforts to improve education. Most of these efforts are related to state legislation and, therefore, must have been initiated before the publication of *A Nation at Risk.* When initiatives of the 50 states and the District of Columbia were considered, it was found that:

> 48 states are considering new high school graduation requirements, 35 have approved changes.
> Initiatives to improve textbooks and instructional materials are reported by 21 states.
> Eight states have approved lengthening the school day. Seven have approved lengthening the school year. Eighteen have mandates affecting the amount of time for instruction. (1984:16)

Some of the proposed changes take place in 1985; others, not until 1989.

In 1983 the Committee on Indicators of Precollege Science and Mathematics was created to lay a foundation for the development of a monitoring system of education for use at national, state and local levels. A report of this project was issued in 1985, in the form of a preliminary review whose scope was limited to indicators constructed from information already being collected or that could be collected with modest extension of present data collection activities. No value judgements were provided, no attempt to investigate underlying causes of observed conditions was made, nor was there any definition of preferred conditions - only portrayals of the current situation (1985:4-5). Committee members looked at three kinds of variables: outcome variables (student achievement), process variables (enrollment in a subject or instructional time spent on a subject or time spent on homework), and input variables (numbers, and quality, of teachers in science and mathematics and the content of the curriculum).

These reports, beginning with *A Nation at Risk* (1983) through the preliminary report on *Indicators of Precollege Education in Science and Mathematics* (1985), all have some relation to the federal government. There are, in addition, general reports such as *The Paideia Proposal, An Educational Manifesto* (Adler, 1982), *High School* (Boyer, 1983), *A Place Called School* (Goddlad, 1984), and *Horace's Compromise* (Sizer, 1984). These more general documents also relate to the status of education in American schools and make recommendations for change - some more radical than others. Their authors write of the passive nature of what goes on during instruction, of the detrimental effects on students of tracking, and of the urgent need to improve school curricula.

What Science Education Research Says

Is the situation in American education and in science education so dismal that there is no hope? This is an overly pessemistic viewpoint. In recent years science education researchers have used the technique of meta-analysis (the analysis of analyses) to study the results of a number of studies on a related topic more systematically than just counting the number of investigations in which a significant difference was reported in favor of the experimental group and comparing that figure with a count of the findings of no significant difference or of a statistically significant difference favoring the control/traditional group.

They have looked at the research in which the effects of innovative science curricula were investigated and at research on instruction and instructional materials. Some of the meta-analysis work was done as part of a study of productive factors in science learning for grades 6 through 12 (Walberg and others, 1980). As a part of this project Weinstein and others (1980) examined 33 studies involving 19,149 secondary school students (in America, Great Britain, and Israel) to assess the impact, during the past 20 years, of innovative precollege science curricula on achievement. The reviewers considered conceptual learning, inquiry skills, attitudinal development, laboratory performance, and concrete skills and examined 13 different curricula (8 at the senior high level, 5 at the junior high level). They reported a ratio of approximately 4:1 in favor of outcomes related to the use of innovative curricula, concluding that these curricula ". . . produced beneficial effects on science learning that extended across science subjects in secondary schools, types of students, various types of cognitive and affective outcomes, and the experimental rigor of the research. . . ." (1980:J12)

In a meta-analysis project focused on the use of the three major activity-oriented elementary school science programs (Elementary Science Study (ESS), Science-A Process Approach (SAPA), Science Curriculum Improvement Study (SCIS)), Bredderman (1983) compared data from 57 studies involving 13,000 students and more than 900 classrooms. Bredderman looked at science process, intelligence, creativity, affective outcomes, perception, logical development, language, science content, and mathematics. The use of activity-based elementary school science programs appeared to promote student achievement in all analyzed outcome areas except logical development (1983:505). Bredderman concluded:

> The accumulating evidence on the science curriculum reform efforts to the past two or three decades consistently suggests that the more activity-process-based approaches to teaching science result in gains over traditional methods in a wide range of student outcomes at all grade levels. (1983:513)

Researchers who participated in a large meta-analysis project directed by personnel at the University of Colorado also looked at materials developed as a result of the NSF-sponsored science curriculum reform movement. Shymansky, Kyle and Alport (*Journal of Research in Science Teaching*, Volume 20, issue 5, 1983) analyzed 105 experimental studies involving 27 different innovative science curricula. They reported that ". . . Across all new science curricula analyzed, students exposed to new science curricula performed better than students in traditional courses in general achievement, analytic skills, process skills, and related skills (reading, mathematics, social studies, and communications), as well as developing a more positive attitude toward science. . . ." (1983:387)

In a related artice (*The American Biology Teacher*, 1984) Shymansky discussed meta-analysis data of the use of materials developed by the Biological Sciences Curriculum Study (BSCS) and reported that the BSCS program was effective in enhancing student attitudes toward science, process skills, analytic skills, and achievement - in that order (1984:55).

Wise and Okey, who also participated in the Colorado meta-analysis project, looked at the effects of various teaching strategies on science achievement and described what they considered to be an effective science classroom:

> . . . The effective science classroom appears to be one in which students are kept aware of instructional objectives and receive feedback on their progress toward these objectives. Students get opportunities to physically interact with instructional materials and engage in varied kinds of activities. Alteration of instructional material or classroom procedures has occurred where it is thought the change might be related to increased impact. The teacher bases a portion of the verbal interactions that occur on some plan, such as the cognitive level or positioning of questions asked during a lesson. The effective science classroom reflects considerable teacher planning. The plans, however, are not of a cookbook nature. Students have some responsibility for defining tasks. (1983:434)

Willis and Yamashita, who also participated in this Colorado meta-analysis project, looked at research related to instructional systems in science education. They concluded, after examining effect sizes, that the most effective innovative instructional systems, in terms of positive cognitive outcomes (as well as other variables) were mastery learning and Keller's personalized system of instruction (PSI) (1983:414).

The use of PSI also was identified as producing stronger results than other types of educational technology in a meta-analysis of 312 studies of the effects of educational technology in college level teaching (Kulik, 1983).

Yeany and Miller (1983), also using meta-analysis techniques, examined 28 experimental studies involving middle school through college students who participated in diagnostic-prescriptive instruction to determine the effect of this instruction on science achievement. They concluded that achievement in science could be significantly and positively influenced through diagnostic remedial instruction, with the influence appearing to come from the diagnostic feedback to students.

Research on time for science instruction is less plentiful than are meta-analysis reports. However, Stallings has provided science educators with some information on this topic. Academic learning time, according to Stallings, consists of (1) time available for academic work, (2) students' time on task, and (3) error rate or appropriateness of seatwork (in Yager, 1982:9). Stallings contends that "interactive instruction" is important: the teacher provides oral instruction for new work, discusses and reviews student work, provides drill and practice, and provides acknowledgement for correct responses and supportive correctional feedback for incorrect responses. Lessons proceed at a brisk pace and at a level that allows for consistent success (in Robinson, 1981:138). Teachers need to teach interactively at least 50 percent of class time if students are to receive the consistant instruction and teacher feedback they need to make achievement gains.

Although Stallings has said that less research on time for instruction has been conducted in science classrooms than in mathematics classrooms, the patterns found are similar.

In advanced classes students get active instruction, demonstrations, and student experiments. In general science classes, students use workbooks and seldom interact with materials or observe demonstrations. This is ineffective instruction, especially for low achieving students (1982:15). Science teachers need to provide several different activities during a class period, use interactive instruction, and create a supportive environment (1982:19). Stallings has provided a comprehensive observation system that can be used in science classrooms to test relationships between classroom instructional strategies and student outcomes (1981:143-145). Her system is composed of two sections: the Classroom Snapshot, used to record the environment and the participants in the classroom; and, following each Snapshot, a five-minute interaction observation focused on the teacher.

The Impetus for Change

If we have positive findings about what is taking place in some science classrooms, as shown in the meta-analysis reports, why is there a need for change? One reason is that the classrooms investigated in the studies focused on the use of innovative science curricula constitute a sample of the general population of science teachers and students in science classrooms. A second reason is that society changes and the forces influencing schools and education change accordingly, forcing change within education. A third reason is that all of the members of the science education community are not in agreement about goals and purposes.

As a result it appears to be easier to focus on problems facing science education rather than to focus on the positive aspects of the current situation. What are some of these problems? A conference held at Exeter Academy (Brinckerhoff, 1980) resulted in a list of seven problems related to science education that, in the opinion of conference participants, threatened the welfare of the nation:

A. There is growing evidence that the United States is falling behind other nations in the areas of science, technology, and science education.
B. There is a decline in enrollment in science courses which is expected to result in an inadequate supply of scientists and engineers as well as an inadequate scientific literacy among the voting population.
C. Lack of confidence in scientific solutions is leading to an increased reliance upon mysticism.
D. The disparity between the scientifically literate and the rest of the population is increasing in our society.
E. There is a decline, in real dollars, of financial support for research and innovation and for education in the sciences.
F. The use of "hands-on" activities in science instruction is growing ever more restricted by budgetary and other constraints.
G. The time alloted to science in the lower grades is diminishing. (1980:8-9)

One of the participants in this Exeter Conference was Paul Hurd who, in 1984 produced a similar list of disturbing trends in science education":

- Decline in science enrollment in secondary schools
- Neglect of science teaching in elementary schools
- Unfavorable attitude toward science acquired in the junior high school
- Drop in achievement test scores in the last decade
- Decline in the number of students aspiring for science careers
- Shortages of qualified science teachers and the likelihood the shortage will worsen
- Low priority assigned by parents to science education
- Failure of science education to respond to changes in science and technology
- Confusion on the part of educators about the goals of science education (1984:1)

According to Hurd,

> . . . The most compelling argument for reforming science education is that science teaching is currently not responding to the intellectual and knowledge demands of a science-technology oriented society. (1984:3)

In advocating further movement in science curriculum reform, Hurd suggests that science educators keep in mind three questions when considering science curricula:

1) What do students need to know in science?
2) How should it be taught?
3) How should the curriculum be structured?

and, when considering curriculum reform,

4) What are the educational advantages to be gained by the proposed changes?
5) What benefits will accrue to society in the long run? (1984:1,8)

Curriculum reform should be guided by the educational purposes we wish to achieve.

Before Change Occurs

Before science educators jump on the curriculum reform bandwagon that appears to be headed toward science-society-technology, they might do well to study some information from Canadian science educators. Orpwood (1985) has described a methodology used in the study of the needs of science education in Canadian schools. Called "deliberative inquiry," this model is based on several assumptions. The first assumption is that school curriculum has both a rational and a political character: rational in that its content should be rationally defensible and political in that it should represent a commitment on the part of certain individuals to act in a particular way. The second assumption is that curricula are politically contentious matters in education and, as such, are resolved through deliberation rather than by needs assessments. The third assumption is that there are stakeholders, individuals and groups who have views about the school curriculum and who desire to influence decisions about it. Stakeholders in the science curriculum are students, teachers, parents, school officials, the scientific community, industry, the labor movement, and others (1985:479-480).

All of these groups need to participate in seeking consensus over new directions for curricula, for three reasons. One, they are entitled to do so because they are affected by the outcome. Two, the absence of key stakeholders will bias the results. Three, the involvement of a broad range of stakeholders will lead to a broader consensus and, therefore, broader support for the conclusions.

Orpwood has described six stages in the cycle of deliberative inquiry:

1. Issue identification: real curriculum problems originate in schools and issue identification is necessary to stimulate awareness and concern, to influence research questions so that an information base about the present situation can be developed.
2. Development of research questions: once issues are identified, it is necessary to develop research questions so that an information base about the present situation can be developed.
3. Uses of theory: theoretical research literature can be used in developing a conceptualization of the issues and their significance.
4. Payoff for theory: the principal results of deliberative inquiry are in terms of changes in policy and practice. If contributions to generalizable knowledge result, these are a bonus.
5. Communication for deliberation: results of the research program must be communicated in a way that is optimal for the deliberation process and should therefore raise questions as often as answer them. The reports should be focused on

the specific context rather than on generalizable conclusions.

6. Payoff for practice: deliberators must decide what to do, with all of the stakeholders involved in this process. (1985:481-483)

Orpwood also differentiates among four levels of curriculum:

- intended curriculum = curriculum guidelines prescribed by departments of education
- planned curriculum = local programs
- taught curriculum = evident in the classroom
- learned curriculum = students' intellectual and practical achievements

Ideally, examination of all four levels should yield identical information but this does not happen. Therefore, evidence from several levels must be gathered to develop a comprehensive view of what is taking place in science education. This can be done by analyzing curriculum policies, analyzing textbooks, surveying teachers, conducting case studies of science teaching, and evaluating student achievement (1985:485).

Because different individuals have differing views about what is important in science education, the idea of curriculum emphases in science education, as explained by Roberts (1982), needs also to be considered. According to Roberts, "A curriculum emphasis in science education is a coherent set of messages to the student *about* science. . ." (1982:245). Such messages may be communicated both explicitly as well as implicitly (by what is not stated as well as by other contextual devices). These seven curriculum emphases are:

Emphasis	Message
Everyday Coping	Science is an important means for understanding and controlling one's environment - be it natural or technological. What is valued is an individual and collective understanding of scientific principles, as a means of coping with individual and collective problems.
Structure of Science	The focus is on how science functions intellectually in its own growth and development, on the interplay of evidence and theory, the adequacy of a particular model for explaining phenomena, the changing and self-correcting nature of scientific knowledge, etc.
Science, Technology, and Decisions	This emphasis concentrates on the limits of science in coping with practical affairs. The set of messages distinguishes science from technology and then distinguishes scientific/technological considerations from the value-laden considerations involved in personal and political decision making.
Scientific Skill Development	The set of messages is that process is more important than product. There is heavy emphasis on means, communicating to the student the implicit message that skillful use of means (scientific process) will automatically yield a correct end (product).
Correct Explanations	In this emphasis science products are stressed as heavily as the previous emphasis stressed processes. Students are expected to master now and question later. The set of messages is on the authority of a group of experts to determine the correctness of ideas.
Self as Explainer	The set of messages in this emphasis deals with character of science as a cultural institution and an expression of one of man's many capabilities. The humanity of science is the student's own humanity.
Solid Foundation	The message here is that science instruction should be organized to facilitate the student's understanding of future science instruction. (What is lacking is any message about the ultimate set of instructional goals toward which all prior instruction is to be directed.) (1982:246-249)

Roberts has suggested that broad curriculum goals can be analyzed to see if these can be clustered into curriculum emphases. Once the emphases are identified, curriculum developers can choose which emphasis to associate with an individual unit of study. Roberts is of the opinion that a curriculum emphasis cannot be made to materialize in less than a five to six week period of time. Because most science courses consist of six to eight units a year, at least three curriculum emphasis could be stressed during a school year. Most science textbooks have only one emphasis, so the adoption of a textbook may not fit with a curriculum plan incorporating different emphases.

A curriculum emphasis expresses a value position. Teachers may have difficulty teaching a unit with a curriculum emphasis of values different from those they customarily hold. However, each emphasis expresses an aspect of science ...ell as reflects legitimate theoretical and practical activities of mankind; none is more relevant than any other, according to Roberts. The greater the range of curriculum emphases in a science program, the more defensible it is. Forces on the curriculum change and shift, so a science program in which curriculum emphases change at different times is more enlightened than a curriculum with a single emphasis (Roberts, 1982: 256-257).

A third Canadian science educator, Aikenhead, also has provided information of interest to curriculum developers who are interested in adding a science and technology focus to the science curriculum. Aikenhead (1985) has argued that two sets of values are involved in issues related to science and technology: constitutive values of science which guide scientists and contextual (ethical, ideological, cultural) values which refer to the social context in which science and technology are carried out. Aikenhead's position is that science and technology are not ethically and politically neutral and that science is laden with contextual values. And, within science, there are the constitutive values of the scientific enterprise and the constitutive values of individual scientists. This apparent conflict in values is pointed up by Holton's reference to public science (that reported in journal articles, conference proceedings, textbooks) and private science (carried out in laboratories and recorded in personal notebooks and letters). Just as Gauld has argued that we do our students a disservice when we teach them only the public set of values, Aikenhead has cautioned that science educators should avoid teaching that science and technology are value free (1985: 457-459).

It is frequently assumed that helping students develop problem solving skills as a part of the science curriculum will enable students to transfer these skills and decision-making abilities to real life. Aikenhead has pointed out that scientists and engineers are not particularly known for making more intelligent choices in their everyday lives than are other individuals. They rarely escape the political context in which they do research (1985:466).

For teachers who are considering using decision-making instruction as a part of their science program in response to Watson's call for including social decision making in science curricula, Aikenhead has developed a 10-item decision making guide. According to Aikenhead, to reach a collective decision on a science-technology based social issue:

1. Itemize the domains of society which appear to be relevant to the issue. These domains include

economics, military, politics, technology, science, law, fine arts, ethics, religion, socio-political ideologies, and others.

2. Identify which domain or agency is given the social authority, or has the political power, to make the ultimate decision. (This process will likely require a class to sharpen the precise wording of the decision or series of decisions to be made.)
3. Generate plausible choices. (Beware of simplistic disjunctives.)
4. Predict the short term and long term logical consequences of each alternative, including the social and psychological consequences.
5. Scrutinize the reasoning relied upon in making those predictions. (What are the warrants and conditions for the knowledge claims made? To what degree are the data valid and reliable? Are any data presented in great vividness?)
6. Clarify the values (constitutive and contextual) that seem to support, or negate, the various alternatives; and recognize the values inherent in the prediction of consequences.
7. Prioritize the values in the context of the issue under decision (an individual task for students.)
8. Weigh the evidence, the probability of the various consequences, and the values underlying the alternatives.
9. Choose one alternative, stating a thoughtful justification.
10. Clarify the ways in which science and technology contributed to this choice. (Science and technology can contribute to the cause of the issue as well as to its resolution.) (1985:467-468)

Aikenhead has identified, for classroom teachers, some pitfalls that hinder decision making. These include students' mythical views of science as well as their lack of realistic appreciation of what can, and cannot, be done with scientific-technological methods and knowledge. A deeper understanding of the facts of science does not lead directly to more thoughtful decisions on social issues related to science.

Teachers should not expect unanimity or a "right" answer in decision making lessons. What teachers should expect is that most students will identify roles that science, technology, values and ideologies play in the resolution of a societal issue.

Teachers and students need to understand the distinction between rational decisions and thoughtful decisions. Also, teachers need to anticipate parents' reactions to the use of controversies in the science classroom and to involve parents early in the process so they understand what their children are discussing and why they are involved in decision making activities.

Finally, teachers need to be aware that if they help their students develop their abilities to reach decisions on social issues related to science and technology, they are encouraging political action and possible conflict with forces within the community (1985:468-471).

Curriculum Questions: Who Decides?

What knowledge is of most worth? What educational beliefs and assumptions are reflected by the curriculum goals of science education? Why should students study science? What kind of science education is most appropriate and for what reasons? Are these decisions reached by consensus of the stakeholders or by some other process?

Science educators have research data relative to instructional materials and techniques, as indicated by some of the meta-analysis research and other studies, but fewer research data exist relative to curriculum goals for science education.

Looking back at the past 20 or more years of science curriculum development, it is possible to identify changes in curriculum emphases, using the seven categories Roberts (1982) developed, and to discern a single emphasis at some point in time. It is also possible, using Orpwood's discussion of the necessity for all stakeholders to be involved in policy formulation and curriculum development, to identify points at which only certain groups of stakeholders were involved in curriculum reform. Will these circumstances be repeated in future activities to establish goals for science teaching and their implementation in curriculum programs and activities? Can repetition be avoided?

National groups and prominent individuals have called for the improvement of American education. State legislatures have responded, with most activities identified as responses begun before national reports critical of education were published and disseminated. Unfortunately, most of these responses have involved increasing requirements for graduation (or for admission to college), adding years of study in science and mathematics with little thought to what such mandates involve.

If we consider precollege science to mean science courses designed to prepare students for further study in science at the college level, we are doing a disservice not only to those students whose plans do not include college study but also to those who plan to enter college but who will major in some discipline other than one of the sciences. As Hodson has written, "Science education in school has to cater for two broad groups of pupils: those who will study science at an advanced level and those who will not. Thus, the science curriculum must be a sound and adequate preparation for later study and must ensure scientific literacy for those others (the majority) who will opt for alternative pursuits. In meeting these two needs it must teach science and teach about science. . . ." (1985:28)

Hodson has raised questions about the adequacy of science teachers' understanding of recent developments in the philosophy of science. He has emphasized that science teachers need some understanding in the philosophy of science and its relevance to science education. In addition to a knowledge and understanding of the philosophy of science, teachers need to be competent in content knowledge. (The authors of *Educating Americans for the 21st Century* differentiated between certified and qualified teachers.) Much has been written about the shortage, present and predicted, of science and mathematics teachers as well as of the poorly qualified teachers, many of whom are minimally prepared to teach science or who are teaching outside their area(s) of certification. How will these individuals be prepared to teach science that is either more of the same or that has been developed to prepare pupils to deal effectively with the future?

Rather than capitalizing on the cries of crisis for opportunities in funding or for causing change, perhaps it is time to engage in some thoughtful deliberations of what science education should be, to demand that suggestions for change be accompanied by supporting rationales that are data (rather than opinion) based, to look carefully at competing philosophies of science as well as philosophies of education, to develop some alternative scenarios and to study the ramifications of each of these if they were to be implemented.

Above all, let us not lose sight of the general education function of science for all students. Most members of the science education community appear to agree that there is confusion over goals and objectives. Is this not the place to begin? In beginning, the past history of science curriculum development and curriculum reform activities, needs to be kept in mind, as well as the political and social orientations of the individuals and groups currently involved in the deliberations.

In 1966 the Educational Policies Commission produced *Education and the Spirit of Science*. This 1966 document reads like one with a more recent copyright date. It contains a discussion of the impact of science and technology today on both developed and developing nations, citing both benefits and causes for anxiety that arise from growth in science and technology. It was the contention of Commission members that the spirit underlying science and technology promised profound benefits: increased individuality but also increased brotherhood (1966:11). Writing that the values on which science and technology are based can penetrate any culture, the Commission advocated that the schools should promote understanding of the values upon which science is based. Commission members considered that the values of science expressed the belief in human dignity. These values cannot be acquired through indoctrination but

> . . . are part and parcel of any true education. These are characteristic not only of what is commonly called science but, more basically, of rational thought - and that applies not only in science, but in every area of life. What is being advocated here is not the production of more physicists, biologists, or mathematicians, but rather the development of persons whose approach to life as a whole is that of a person who thinks - a rational person . . . (1966:16)

A further statement of the Commission is particularly relevant for these times in which excellence is being equated with increased graduation requirements:

> It cannot be assumed that the addition of science courses to a curriculum would necessarily contribute to the achievement of these goals. Indeed, science can be so taught as to be irrelevant or even opposed to their achievement. Efforts to discourage challenges to traditional beliefs and attempts to indoctrinate are probably widespread in every school system, however advanced the content of science courses. What is needed is an education which turns the child's curiosity into a lifelong drive and which leads students to consider seriously the various possibilities of satisfying that curiosity and the many limitations on those possibilities. (1966:23)

In Summary

Persons interested in improving science education have some positive findings from the meta-analysis research data upon which to build in terms of instructional strategies that lead to increased student learning and other positive outcomes. However, science for general education purposes should not be neglected; we [illegible]l to educate both the citizen and the future scientist. Whatever changes are made should be based on rational decisions reached by consensus of all of the stakeholders involved. In making changes in science curriculum and instruction, the teachers who are going to have to implement these materials and activities in the classroom must also be considered. If they do not understand and agree with the reasons for change, and if they do not possess the knowledge and skills to effectively use these changes, improvement is not likely to occur.

REFERENCES

Adler, Mortimer J. *The Paideia Proposal, An Educational Manifesto,* New York: MacMillan Publishing Company, 1982.

Aikenhead, Glen S. "Collective Decision Making in the Social Context of Science." *Science Education* 69(4): 453-475, 1985.

Blosser, Patricia E. *Recommendations for Improving the Science Curriculum.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, December 1985. SE 046 340

Bredderman, Ted. "Effects of Activity-Based Elementary Science on Student Outcomes: A Quantitative Analysis." *Review of Educational Research* 53(4):499-518, Winter, 1983.

Boyer, Ernest L. *High School: A Report on Secondary Education in America.* New York: Harper & Row, Publishers, 1983.

Brinckerhoff, Richard F. et al. "The Exeter Conference on Secondary School Science Education." Exeter, NH: Phillips Exeter Academy, June, 1980. ED 210 184

Educational Policies Commission. *Education and the Spirit of Science.* Washington, DC: National Education Association, 1966.

Goodlad, John I. *A Place Called School, Prospects for the Future.* New York: McGraw-Hill Book Co., 1984.

Harms, Norris C. and Robert E. Yager, eds. *What Research Says to the Science Teacher, Volume 3, Project Synthesis.* Washington, DC: National Science Teachers Association, 1981. ED 205 367

Helgeson, Stanley E., Patricia E. Blosser, and Robert W. Howe, *The Status of Pre-College Science, Mathematics and Social Studies Education, 1955-1975, Volume I. Science Education.* Washington, DC: Government Printing Office, 1978. ED 153 876

Hodson, Derek. "Philosophy of Science, Science and Science Education." *Studies in Science Education* 12:25-57, 1985.

Hurd, Paul DeHart, "Reforming Science Education: The Search for a New Vision," Occasional Paper 33. Washington, DC: Council for Basic Education, 1984. ED 242 515

Kulik, James A. "How Can Chemists Use Educational Technology Effectively?" *Journal of Chemical Education* 60(11):957-959, November, 1983.

National Commission on Excellence in Education. *A Nation at Risk: The Imperative for Educational Reform.* Washington, DC: U.S. Government Printing Office, 1983. ED 226 006

The Nation Responds, Recent Efforts to Improve Education. Washington, DC: U.S. Department of Education, May, 1984. ED 240 748

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. *Educating Americans for the 21st Century.* Washington, DC: National Science Foundation, 1983. ED 233 913

Orpwood, Graham W.F. "Toward the Renewal of Canadian Science Education, I. Deliberative Inquiry Model." *Science Education* 69(4):477-489, 1985.

Raizen, Senta A. and Lyle V. Jones, eds. *Indicators of Precollege Education in Science and Mathematics.* Washington, DC: National Press, 1985.

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Roberts, Douglas A. "Developing the Concept of 'Curricululum Emphases' in Science Education." *Science Education* 66(2):243-260, 1982.

Robinson, James T. *Research in Science Education: New Questions, New Directions.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, June, 1981. ED 209 075

Shymansky, James. "BSCS Programs: Just How Effective Were They?" *The American Biology Teacher* 46(1): 54-57, January, 1984.

Shymansky, James A, Wm. C. Kyle, and Jennifer C. Alport. "The Effects of New Science Curricula on Student Performance." *Journal of Research in Science Teaching* 20(5): 387-404, 1983.

Sizer, Theodore R. *Horace's Compromise, The Dilemma of the American High School.* Boston, MA: Houghton Mifflin Co., 1984.

Stake, Robert E., Jack Easley et al. *Case Studies in Science Education, Volume I, The Case Reports.* Washington, DC: U.S. Government Printing Office, 1978. ED 166 058

Stake, Robert E., Jack Easley et al. *Case Studies in Science, Education, Volume II, Design, Overview and General Findings.* Washington, DC: U.S. Government Printing Office, 1978. ED 166 059

Stallings, Jane. "Applications of Classroom Research of the 1970s to Mathematics and Science Instruction," Ch. 2 in *What Research Says to the Science Teacher,* Volume 4, Robert E. Yager, ed. Washington, DC: National Science Teachers Association, 1982.

Stallings, Jane. "Classroom Research: Implications for Mathematics and Science Instruction," Ch. 9 in *Research in Science Education: New Questions, New Directions,* James T. Robinson, ed. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, June, 1981. ED 209 075

What are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field. Washington, DC: National Science Foundation, 1980. ED 193 051

Weiss, Iris R. *Report of the 1977 National Survey of Science, Mathematics and Social Studies Education.* Washington, DC: U.S. Government Printing Office, 1978. ED 152 565

Walberg, Herbert J. et al. *A Meta-Analysis of Productive Factors in Science Learning Grades 6 Through 12.* Chicago, IL: University of Illinois at Chicago Circle, June, 1980. ED 197 939

Weinstein, Thomas et al. "Science Curriculum Effects in High School: A Qualitative Synthesis" in *A Meta-Analysis of Productive Factors in Science Learning Grades 6 Through 12,* Herbert J. Walberg et al. Chicago, IL: University of Illinois at Chicago Circle, June, 1980. ED 197 939

Willett, John B. and June J.M. Yamashita. "A Meta-Analysis of Instructional Systems Applied in Science Teaching." *Journal of Research in Science Teaching* 20(5):405-417, 1983.

Wise, Kevin C. and James R. Okey. "A Meta-Analysis of the Effects of Various Science Teaching Strategies on Achievement." *Journal of Research in Science Teaching* 20(5):419-435, 1983.

Yager, Robert E., et. *What Research Says to the Science Teacher, Volume 4.* Washington, DC: National Science Teachers Association, 1982. ED 225 871

Yeany, Russell H. and P. Ann Miller, "Effects of Diagnostic/Remedial Instruction on Science Learning: a Meta-Analysis." *Journal of Research in Science Teaching* 20(1):19-26, 1983.

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