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ABSTRACT

A major study of Canadian science education was undertaken in 1980 to establish a documented basis for describing the present purposes and general characteristics of science teaching in Canadian schools, to provide an historical analysis of science education in Canada, and to stimulate active deliberation concerning future options for science education in Canada. The research provided a database for a nationwide series of conferences which were held to discuss the questions raised by the study and to explore future directions for science education in Canada. This document, a summary of the study, is designed for a more general audience. Its purpose is to encourage continuing deliberation about the issues by science educators and others concerned with the quality of Canadian science education. Major areas addressed include: (1) curriculum guidelines (what they prescribe); (2) textbooks (what they teach); (3) teachers (who they are and what they think); and (4) classrooms (how science is actually taught). Each of these areas is followed by a list of issues to consider. (JN)

The English and French summaries of this Background Study have been prepared separately. The summaries represent the views of the authors and not necessarily those of the Science Council.

Preface

This document is a summary of the three-volume Background Study of the Science Council of Canada, *Science Education in Canadian Schools*. The individual volumes of the complete study are as follows:

I. *Introduction and Curriculum Analyses*
by Graham W.F. Orpwood and Jean-Pascal Souque

II. *Statistical Database for Canadian Science Education*
by Graham W.F. Orpwood and Isme Alam

III. *Case Studies of Science Teaching*
edited by John Olson and Thomas Russell

Together, these volumes constitute the research portion of a study on Canadian science education conducted by Council between 1980 and 1983. This research provided a database for a nationwide series of conferences which were held to discuss the questions raised by the study and to explore future directions for science education in Canada. The research is now being made available to a more general audience, in the form of the Background Study, to encourage continuing deliberation about the issues by science educators and others concerned with the quality of Canadian science education.

Conclusions and recommended policy initiatives based on the Background Study are contained in a separate Science Council Report entitled: *Science for Every Student: Educating Canadians for Tomorrow's World*. Copies of Report 36, of its summary, and of the Background Study can be ordered using the form at the back of this booklet.

Science Education at a Crossroads

In the late seventies, Canadian elementary and secondary schools were sharply criticized for the way in which science was being taught. In the report of the Commission on Canadian Studies published in 1975, Professor Thomas Symons accused schools of teaching children "virtually nothing about the impact of science in their own country."* According to Symons, science was being taught as a body of knowledge and technique, without any mention of its personal, social or national relevance. David Suzuki, a geneticist and well-known broadcaster, claimed that schools were perpetuating the separation of arts and science as "two cultures," so that potential scientists learned nothing of their moral responsibility to society, while members of even the educated public remained ignorant of the enormous impact of science and technology on their lives. In *École + Science = Échec* (School + Science = Failure), Jacques Désautels charged that Québec schools were not developing scientific attitudes among students and that they were decreasing rather than increasing interest in science, promoting élitism and, in short, miseducating those they should be educating.

If the critics were right, the consequence for Canadians would be serious. A public that did not understand science or its impact on society would be at the mercy of technological change, not in control of it.

In the spring of 1980, the Science Council of Canada began a major study of science and education in Canada. By examining the past and present objectives and methods of Canadian science education, Council hoped to stimulate active deliberation on the issues among as many as possible of those who have a stake in the science education enterprise. The aim of these deliberations was to explore future directions for science education in Canada.

*T.H.B. Symons, *To Know Ourselves*, Report of the Commission on Canadian Studies, Association of Universities and Colleges of Canada, Ottawa, 1975, Volume 1, p. 162.

Too often, decisions about curriculum change have been made exclusively by educators. These people often follow a highly rational, linear process in assessing needs and developing instructional strategies to meet them. But individual children and society in general have a bewildering variety of what can be called "needs," and the process of making curriculum involves the resolution of conflicting needs, which implies a political decision. This process must be deliberated over, and in a democratic society all who have a stake in the outcome have the right to participate in such deliberations. Those responsible for decisions must weigh conflicting advice to ensure that future directions are not determined by the loudest shout or the most devious political manoeuvre.

For this reason, the deliberations were designed to include individuals both inside and outside the system: students, teachers, university professors, school board members and employees of the ministries of education on the one hand, and parents, scientists, industrialists, government officials and members of the general public on the other.

What are the Problems?

To pinpoint the problems facing Canadian science education, specialists from different fields were asked to provide their perspective on science teaching in Canada today. Council published their views as a series of discussion papers to stimulate debate.

In *A Canadian Context for Science Education*, James Page argues that science education in Canada lacks Canadian content. Page, a specialist in Canadian studies, maintains that if schools are to produce Canadian citizens aware of their cultural heritage, an understanding of science as part of the cultural fabric of Canada is necessary.

In *Science in Social Issues: Implications for Teaching*, Glen Aikenhead points out that science is now taught as if it were all- and self-sufficient. Aikenhead, himself experienced in both science-teaching and curriculum research and development, believes that an educated person should be capable of taking part in and understanding social and political decisions. An understanding of science is but one among many ways of knowing, he says.

"At present, only the skills of the scientist are taught," charges Donald George, a professional engineer and university teacher. In *An Engineer's View of Science Education*, he suggests that schools should produce people capable of solving practical problems.

What is Scientific Thinking? asks Hugh Munby. Munby, an experienced teacher and teacher educator, believes that current teaching practice fails to produce independent thinkers who understand properly the basis of their knowledge.

Marcel Risi, former commercial director of the Centre de recherche industrielle du Québec (CRIQ), thinks that science is taught only as a body of knowlege. In *Macroscole: A Holistic Approach to Science Teaching*, he criticizes schools for not developing educated people with a "sceptical, divergent, questioning and imaginative approach" towards the solution of problems.

Describing how educators can combine all these diverse objectives in the science curriculum is the task undertaken by Douglas Roberts. A professional educator and member of Council's committee on science and education, Roberts outlines his proposals for a comprehensive and balanced curriculum in *Scientific Literacy: Towards Balance in Setting Goals for School Science Programs*.

Still another problem was raised at a workshop conducted by the study committee: science teaching in Canadian schools is not taking sufficient account of the different needs of boys and girls. That this is so is clear from the fact that girls tend to drop science courses much earlier than do boys.

The views expressed in the discussion papers and in the workshop appeared to confirm the earlier criticisms of Symons, Suzuki and Désautels. On further examination, these criticisms were seen to be concerned not so much with the content of science teaching as with the ways in which students are taught and the purposes for which they learn science. For this reason, the research phase of the study focussed on the official objectives and strategies for science teaching.

Four major research projects were undertaken. Together they provided a view of the teaching of science, both at the level of rhetoric (what is said about science education) and at the level of practice (what actually takes place). The projects involved:

- an analysis of science curriculum guidelines issued by ministries of education in the provinces and territories of Canada;
- a descriptive analysis of 34 science textbooks in use in Canadian schools;
- a survey of science teachers and their views about teaching science, involving nearly 7000 teachers in 1227 schools across the country;
- case studies of actual science teaching practice in 8 Canadian schools.

The results of this research, and the questions it raised, are summarized in the following pages.

Curriculum Guidelines: What Do They Prescribe?

A decision made by a teacher about what or how to teach is simply the last in a chain of decisions, many of which have been made outside the school to cover broad categories of situations. Whether they are made at the ministry, school district or school level, these decisions combine to form a context which sets limits within which individual teachers do their specific planning for the day or week.

The first of the decisions in this chain are made by ministries of education. Working (typically) with committees of science educators, ministry officials draw up guidelines covering each subject or course at each level of schooling. Teachers and other insiders have ample opportunity to take part in the process, but parents, industrialists, business people and those outside educational circles are rarely involved. This system produces a tendency to conservatism because the range of value positions represented is rarely wide. The guidelines specify which subjects must be offered, how much time should be spent on each subject, the requirements for graduation, and so on. For each science subject, they also specify aims, content and, to a certain extent, teaching strategies to be implemented in schools.

In all provinces, a basic core of science is taught through elementary and secondary schools. In the early years* science is integrated with other subjects but it gradually becomes separated during the middle years. Separate courses in physics,

*For purposes of the study, the "early years" were defined as including grades one through six (or seven, in two provinces). Similarly, the "middle years" encompass grades seven to nine (or ten, in two provinces), and the "senior years," grades ten (or eleven) to thirteen. "Science" was taken to be those areas of the school curriculum designated in each province and territory as "science." In practice, this meant that mathematics and social studies were excluded from the study, while physical, biological and earth sciences were included, as was a large grey area of subjects such as computer studies, agriculture and technology that are designated differently in different provinces.

chemistry and biology emerge in the senior years in all provinces.

Throughout Canada, students in the early years of schooling have no choice: science is a required part of the curriculum. The same is true, in most places, for the middle years. By the senior years, students may select from a variety of science courses, and different provinces require students to take different numbers of them in order to graduate. In 9 of the 12 jurisdictions, only one science course beyond the end of grade 9 is required. Two are required in Manitoba, while in Prince Edward Island and Nova Scotia none are required. These are minimal requirements for graduation purposes, but individual districts or schools can set higher requirements.

Between them, the curriculum guidelines issued by ministries of education in Canada offer eight answers to the question, "Why teach science?".

*To teach students the basic concepts in science in a way that will enable them to understand and manipulate scientific information.** This aim emphasizes the value of knowing scientific facts rather than how they were developed or might be applied. It is frequently recommended for those who teach in the early years of schooling by those who teach at higher levels, and is a major goal of science education in every province and territory at every level.

To develop skill in using the methods and tools of science. In recent years, teaching students to observe, classify, measure, draw inferences and make hypotheses has become an increasingly popular reason for teaching science. This objective is also common to most provinces at all three levels.

To promote an understanding of the relationship between science and society. This objective is relatively new. It reflects a degree of popular scepticism about the social and economic

*This and subsequent statements of objectives are examples taken from actual curriculum guidelines.

potential of science, and a greater awareness in recent years of its limitations. It requires teachers to deal with problematic ethical issues such as energy use, genetic engineering and industrial waste. It is more popular in the middle years than in the early or senior years.

To teach students about the nature of science and its value as a way of learning and communicating about the self, the environment and the universe. Here, the goal is to explain how science works as a discipline. This objective makes considerable use of the history of science and is included in secondary school guidelines in most provinces.

To help students develop as autonomous and creative individuals who live in a scientific and technological society. According to this objective, schools teach science in order to promote students' personal growth, both intellectual and moral. This objective is found in curriculum guidelines for the lower grades in all provinces (it disappears from the guidelines for the senior grades), but no directions are given to teachers for achieving it.

To develop in students attitudes characteristic of scientists (intellectual honesty, openmindedness, desire for accurate knowledge) and appropriate attitudes towards science in general (enthusiasm, appreciation, excitement). This is a popular aim for science teaching in the early years.

To expose students to a representative sample of the technological applications of science. There has recently been renewed interest in this aim which, after a period of popularity in the forties and fifties, was displaced by the objective relating to the nature of science.

To prepare students to take advantage of career opportunities in technology, industry, commerce and business. Adopted in many provinces, this aim is hotly debated by those who believe that schools are not for job training.

Overall, there is considerable consensus among ministry guidelines as to the aims of science education in the early years of schooling, where the emphasis is on process skills and attitude development. In the middle years, a distinct shift occurs towards learning science content for its own sake. Process skills are still emphasized, but science-and-society aims become more popular. Guidelines for biology, chemistry and physics suggest there is less consensus about aims at the senior level, though a movement away from aims of personal growth and development of attitudes, in favour of learning about the nature and applications of science, can be noted.

It would appear that the five issues raised in Council's discussion papers are not stressed in policy documents. The guidelines contain only very occasional references to the need for a Canadian context. (There are exceptions to this: programs in the Northwest Territories to help students understand science as it applies to their own unique environment, and agricultural programs in Prince Edward Island, are two examples.) The relationship of science to other curriculum subjects is almost never discussed in the guidelines, and although many middle-years guidelines speak of the need to teach about the interaction of science, technology and society, schools appear to have largely ignored this topic. The guidelines make no mention of the processes of engineering referred to by Donald George, although there are occasional references to technology and the products of applied science. There is no reference, at any level, to the separate needs of boys and girls.

When it comes to suggesting *how* science should be taught, ministry guidelines are strangely mute. Teaching strategies for the early and middle years are limited, for the most part, to injunctions that science programs should be "activity based" or should use "the inquiry approach." There is also little in the way of prescription for the senior years.

Mostly, ministries influence how teachers teach by approving textbooks. The degree of control over the use of specific textbooks varies from province to province. British Columbia, for example, prescribes mandatory use of a very limited range of textbooks at each level, whereas Ontario and Québec have traditionally authorized wide selections of books from which schools have the right to choose.

Issues for Deliberation

- How many different objectives can a program realistically be expected to attain? Are all aims of equal value? If not, what priorities should be established among them? (Not one guideline document sets out an order of priority among the diverse aims.)
- How can teachers teach the content of science as well as attend to some of the other objectives?
- Given that guidelines rarely establish a hierarchy of process skills to be taught, is there a danger that only lowest-level skills will be attended to?
- How can teachers integrate the subject matter of science with that of social studies, mathematics and the technical fields?
- How can teachers impart attitudes characteristic of scientists, and good attitudes towards science in general, without opening themselves to accusations that they are indoctrinating students?
- What methods could teachers use to place their lessons more within a Canadian context, teach practical engineering skills or take account of the separate needs of boys and girls?
- Will existing procedures, which are supported by teachers, allow science curricula with different objectives to be developed, or will new procedures and the participation of different people in the making of policy decisions be needed if change is to occur?

Textbooks: What Do They Teach?

Until recently, single textbooks comprised the entire science program, but the new emphasis on training in the scientific method and the concern for individualizing instruction that emerged during the 1960s prompted ministries to recommend a wider range of textbooks. Today, 174 science textbooks are officially approved across Canada, while surveys show that 250 different books are actually used in science classrooms (most unapproved textbooks are used as supplementary aids at senior levels). Of these, two-fifths were published before 1975, and one-fifth more than 12 years ago. These statistics are significant because it is the newer books which tend to avoid stereotypes and introduce greater Canadian content and social perspective.

Although ministries decide which textbooks *can* be used, and school boards and schools have some say, the final choice of a textbook for use in the classroom rests with the teacher. Across Canada, 6 of every 10 early-years teachers use no science textbooks in their classrooms. (There is considerable variation here, as this statement applies to 90 per cent of Ontario teachers, but to only 3 per cent of Newfoundland teachers.) By contrast, textbooks are used by 75 per cent of teachers in the middle years and 90 per cent of teachers in the senior years. Generally, teachers find textbooks to be the most useful aid in the preparation of science courses, although early-years teachers prefer to use libraries, museums, science fairs and other learning resources.

Teachers' satisfaction with the textbooks they use is generally quite high, particularly in the case of physics, biology and chemistry textbooks used in the senior years. Most teachers give textbooks high marks for their use of illustrations (particularly in textbooks for the early years), readability, suitability for the intellectual maturity of students, and the degree to which textbooks' objectives and priorities agree with their own. Low marks are given for the use of Canadian examples and for accounts of the applications of science. Although most books are judged to be suitable for fast learners, few, if any, are thought suitable for both fast and slow learners.

How well do textbooks fulfil the aims laid down by ministry guidelines? Broadly speaking, textbooks conform rather well to official objectives for science education, although statements of aims within textbooks are sometimes vague or incomplete, and it is not always clear to whom they are addressed. Considerably more attention is given to scientific content and procedures than to the social implications of science and technology, and three of the eight objectives endorsed by ministries — development of science-related attitudes, the study of applied science and technology, and encouragement towards careers — receive little emphasis.* The issues raised by the authors of Council's discussion papers do not seem to be among the priorities of the textbook writers. The point of view of the engineer is almost entirely missing, and the special needs of girls are not given any emphasis (although the crudest stereotypes have been eliminated).

Ninety-five per cent of experiments suggested in the textbooks are highly structured. Students are seldom asked to formulate a question or define a problem. Laboratory manuals used in the senior grades generally ask students to verify laws previously learned in class (the deductive approach) rather than to generalize from information they themselves have collected (the inductive approach). At all three levels, textbooks rarely ask students to work together during laboratory sessions. Although attention is given to acquiring scientific skills, most textbooks confine themselves to the development of fairly elementary skills.

Of the activities suggested by textbooks to help students apply what they have learned, only one-fifth are invitations to direct action in the home or community; the rest are of a

*The study did not analyze the scientific content of textbooks, but rather the context in which that content is presented.

reflective nature. A number of texts discuss the effects of science and technology on society (there is rough parity between good and bad effects), but the majority of these discussions occur in the last chapter and are dealt with perfunctorily. Statements concerning the effects of science and technology claim that they:

- result in progress which creates pollution, overpopulation, illness and disturbance to the environment;
- invent medicines and techniques for improving health;
- create machines or processes to facilitate work or increase wellbeing;
- discover beneficial new materials and new sources of energy;
- waste energy and resources and create waste disposal problems;
- induce people to conserve resources and energy and take action against pollution.*

Moral problems (for example, the ethics of genetic engineering or whale hunting) and political matters (waste disposal, deforestation, third-world development) receive scant attention.

In terms of offering a Canadian perspective, science textbooks used in Canadian schools teach almost nothing about science and technology in Canada, or about its history and impact on society. Some books contain population statistics for the United States, but none for Canada; list the racial types in the US, but not in Canada; mention American universities as career goals, but ignore Canadian universities — the list is endless. Where Canadian references do occur, they usually concern problems of pollution and energy. Mining is rarely mentioned as an important factor in Canadian life, while the

*Listed in order of decreasing frequency of appearance.

northern character of Canada, its lifestyle and form of government as these relate to science and technology are virtually ignored. The history of science and technology in Canada is also treated inadequately, though references to famous Canadian scientists, such as Sir Sanford Fleming and Sir Frederick Banting, abound. Almost no information is given about career possibilities in science and technology in Canada. The books with the least information on Canada are those used in the early and senior years. Significantly, French translations of American works contain more Canadian content.

Concerning the nature of science, most textbooks tell students that science represents both a product and a process. Half the textbooks used in the middle and senior years describe the scientific method as including the following steps: definition of the problem, observation, gathering of information, formulation of hypothesis, designing the experiment with controlled variables, verification and communication of results. There are implied suggestions in these accounts that not only is this how scientists do, in fact, work, but that this is how students should work as well.

Though ministries and teachers assign little importance to teaching the history of science, few textbooks ignore this topic altogether. Historical accounts range from simple lists of the names of scientists and the dates of their discoveries to detailed case studies, though these facts are seldom placed in an historical or social context. Few authors explain the importance of learning the history of science, and those who do are not always clear or straightforward in their attempts.

Issues for Deliberation

- What is the distribution of statements in textbooks concerning the social consequences of science and technology telling students? What effect are these messages having on students' developing attitudes?
- Textbooks teach that scientific inquiry is basically inductive in nature and is based on cooperation and communication. Yet laboratory sessions are not organized to favour this approach. How can learning experiences in the laboratory be designed to better reflect science as it is actually practised?
- How can laboratory tasks be designed to teach higher-level process skills?
- If to understand the nature of science is a major educational objective, should not students and teachers be more aware of the messages concerning this subject found in textbooks?
- Is "textbook science" — that version of science which has become standardized, even stereotyped, by repetition in generations of textbooks — an acceptable model? Do policies such as these in Québec, which require authors to prepare textbooks in accordance with prescribed objectives, constitute a step away from this standardization, or are other measures necessary? Is "the child as scientist" a proper model for teaching scientific thinking?
- Because textbooks remain one of the main instruments by which the aims of science curricula are reached, should not educators have a better understanding of their impact on students' [illegible]?

Teachers: Who Are They and What Do They Think?

More than 98 000 people are teaching science in Canadian elementary and secondary schools. Most are between 25 and 45 years of age, hold university degrees and have more than 10 years' teaching experience. Exceptions to the rule include Québec teachers who tend to be older than the norm, and Newfoundland and Alberta teachers who tend to be younger. A small but definite shift is underway towards more male teachers in the early years and more females in the senior years, where males still outnumber females eight-to-one. On average, male teachers are slightly older and significantly more experienced than their female counterparts. Urban teachers are more experienced than rural teachers.

Most science teachers are enthusiastic about teaching science. Those who are not usually cite their lack of qualifications. Generally, the longer they have been teaching science, the more satisfied teachers are with their work.

How do teachers feel about the educational objectives set out in ministry guidelines? Strong support is given by early-years teachers to those objectives that involve attitudes, process skills and social skills. The learning of scientific content is valued more highly by those with less than 10 years' experience than by those with more.

Even more importance is attached to these objectives by middle-years teachers, who also vote strongly on behalf of teaching science content, the relationship between science and society, the practical applications of science, skill in reading and understanding scientific literature, and the value of science for building and expressing students' understanding of the world. These objectives reflect the broader variety of purposes for which science is taught in these years. "Relating science to the needs and interests of both men and women" and "learning about the practice of science in Canada" are both valued more highly as educational objectives by female than by male teachers. These two objectives are also more popular among urban teachers.

Teachers in the senior years, while supporting all official aims for science teaching, find the same group of objectives chosen by middle-years teachers to be the most important. Again, female teachers accord greater importance to objectives dealing with the relevance of science for men *and* women, and the need for a Canadian context.

Teachers' views of individual objectives differ somewhat from those of ministry officials who devise them. Although there is little disagreement about the importance of teaching content, scientific skills and appropriate attitudes towards science, there are still questions about which skills should be taught at which levels and how the teaching of content can be combined with the achievement of other aims. Further, most teachers feel that learning the content of science is more important in the higher grades than in the lower. "Science and Society" objectives are rated high by all teachers, but these same teachers assign little importance to increasing students' awareness of science as it is practised in Canada. On this point at least, teachers, guidelines and textbooks seem to be in agreement. The critics are right: science is *not* taught in schools as part of the cultural fabric of Canadian society.

Objectives that focus on teaching the nature of science receive little support from teachers, who feel that only the brightest students can achieve them. Personal growth objectives are considered important at lower levels, less so at higher levels. Objectives implying that special attention be given to the needs of girls in science education receive little support, indicating that teachers, as well as ministries, are generally unaware of the low participation of women in the professional science community. Both teachers and ministries show ambivalent attitudes towards applied science and technology objectives: aims concerned with the practical applications of science are rated high at all levels, but those dealing with the skills of engineers and technologists are rated low. Teaching science as it relates to the students' conception of the world is regarded as important by teachers at all levels, but preparing students for career opportunities is seen as an important part of science teaching only in the senior years.

In general, teachers believe they are most successful in achieving those objectives they consider most important. There are a few exceptions: teachers in the early years feel they give insufficient attention to the separate needs of boys and girls, while teachers in the middle and senior years feel the "science and society" objectives receive inadequate treatment. Senior teachers also question their success in developing reading skills and students' ability to understand scientific literature. They are unsure about how well they have related scientific explanations to students' conception of the world. These assessments are inevitably subjective. More reliable measurements of teacher effectiveness will have to wait until improved techniques are developed for evaluating how well students learn.

As has already been noted, teachers rely heavily on text-books (which they generally find to be of acceptable quality) for planning their courses. They make surprisingly little use, however, of ministry guidelines and other materials not produced specifically for teachers. Overall, teachers find that the time allocated for teaching science is sufficient, but some of them (early-years teachers in particular) complain of inadequate physical facilities and equipment, and poor support for their work from schools and school boards. Physical facilities are considerably better in the senior years, where three out of four teachers have a regular laboratory equipped for experiments by students. Teachers at all levels complained of ineffective (or, in the case of early-years teachers, largely nonexistent) inservice training.

Issues for Deliberation

- Because of declining enrolment, many school systems have stopped recruiting teachers; some have laid off their youngest staff members. This factor has contributed to the increasing age and experience of the science-teaching force. But given that younger teachers are among the best qualified and more equally balanced between the sexes, what will be the effect on science teaching if this trend continues?

- As a rule, teachers are becoming better educated, but:

  - half of all science teachers have not taken a university-level course in mathematics or science in the last ten years;
  - more than half of all early-years teachers, and more than a third of middle-years teachers, have never taken mathematics or science at university level.

  In view of these statistics, should the requirements for teacher certification be changed?

- Significant numbers of teachers, especially at the senior level, have had some experience in science outside the academic world. Such experience is a valuable teaching resource. How can such work experience be recognized and encouraged, and how can it best be used for the benefit of students? How can industry become involved in the science education of our children, without diminishing the integrity of teachers and their responsibility towards students?

- Generally, teachers assign low priority to the objectives outlined by the authors of Council's discussion papers. Are the teachers right, or are the critics? What priorities should be established among the objectives for science education? What relative importance should be given to science at each stage of a student's education?

- Are existing resources adequate for objectives to be met? How can other useful materials (such as government publications) be made more accessible to teachers? How can computer technology serve as a curriculum resource for teachers? How can the resources available in secondary schools be used to assist science teachers in the middle and early years?

- How can inservice teacher education be made more effective? Can elementary school teachers be given more opportunities to benefit from such training?

- Most teachers believe boys and girls to be equally able and motivated to undertake science courses, but some teachers think that boys in the early years, and girls in the senior years, are more highly-motivated. Does science teaching adequately capitalize on the interests and abilities of all students? How can science activities outside the school (which students find interesting) be better related to what students do inside the school? How can teachers ensure that girls, who drop out of science at a higher rate than boys, will take an active interest in science?

Classrooms: How Is Science Actually Taught?

In practice, teachers are concerned with maintaining their credibility, exerting their influence, gaining access to scarce resources, coping with conflicts between outside expectations and the realities of the classroom, coping with a lack of skill to teach science as innovators imagine it should be taught, fulfilling the expectations of authorities and resolving conflicts between students' interests and the demands of the subject.

In the early years of schooling, about 10 per cent of available time is allotted to science. To save time and arouse student interest, some early-years teachers integrate science with related topics; others outside the early years regard such integration with some suspicion as a "softening" of science experience. Curriculum policy documents encourage integration of subjects, but do not say what science topics should be taught or how they should relate to science work that comes later. This leaves early-years teachers free to follow student interests, which may lead to a little science or a great deal of it, depending on the teachers' own inclinations.

For the most part, teachers in the early years tend to be isolated within the school, by circumstance and by tradition. Cooperation seems to be difficult to arrange and maintain. The presence of a science expert appears not to be an effective way of disseminating ideas about the teaching of science.

In the middle years, the emphasis is on covering a considerable body of material in the time available. "Covering the material" means that the "correct" explanation must be included in students' notes. Teachers stress the specialized vocabulary of science, access to which is controlled through notes and activity sheets designed by teachers.

Teachers in the middle years complain that at this level students are not easy to teach: class control is a central concern. They speak ruefully about the lack of student interest and about how hard it is to engage students intellectually. They worry that students have become afraid of science because of teacher attitudes in the early years.

Middle-years teachers emphasize routines, standards of accuracy and thoroughness. For them, accuracy is at the heart of what they believe to be a scientific approach to problems. This emphasis on approved explanations and the right answer is at odds with the process of inquiry and the conceptual and tentative status of knowledge in science. Yet, such predictable activities as note-taking, copying activity sheets and lab procedures are valued because the accumulated information provides a base for work in the next grade, and because they control and channel energies by keeping students busy with routine, unambiguous work. Teachers appear reluctant to introduce into their well-ordered and coherent system any activity that might upset the smooth running of things. These teachers seem to make very restricted use of the potential that science has for general education.

Senior-years teachers view science as a precise method, and as a system of exact numbers, highly organized bodies of information and specialized terminology. Their concern is to provide students with the notes and with the practice in solving problems that will result in high marks on examinations and allow the student to move through high school to university. Work in the lab is geared towards *illustrating* facts and theories presented in the classroom, *confirming* what is discussed in class, obtaining precise facts and getting the right answers to problems. Activities are designed to develop in students habits of diligence, self-reliance and tidiness. Students are encouraged to become systematic and objective.

Alternative approaches, such as those emphasizing the inquiry process or the relation of science to social issues or technology, are not seen as central activities for the science classroom, but as a means of encouraging interest. Similarly, optional work, though interesting, is not essential and uses up time needed to cover the less interesting "real" work. Teachers are aware of the dilemmas inherent in their work, and many are unhappy about the trade-offs they are constantly making. They recognize that an inquiry approach might help students to better understand what they are doing, but they reject such an approach and the use of optional topics for several reasons: "The daily routine does not allow for such reflection"; "That type of work doesn't sink in"; "It's difficult to evaluate"; "There's no academic value in looking at science-and-society issues"; "Nature-of-science topics take away time from content"; "Such an approach isn't efficient."

Perhaps the practice of these teachers in the classroom reflects their views on the nature of their work. Senior-years teachers appear to believe that students find it difficult to infer relationships and explore the implications of theories on their own. They believe that students need to be encouraged to learn, that they want grades as success tokens, need teachers to "boil down" the material for them, and enjoy seeing a definite end product to their work. In their opinion, students are easily distracted, want push-button answers and cannot read or do math. They are convinced that parents want teachers to ensure the success of their students and that universities want students who have been well-prepared for post-secondary work. They do not consider themselves competent to lead discussions about subjective issues.

Given these beliefs, would optional work and the inquiry approach be viewed by teachers as any less peripheral if more time for them were, in fact, available?

On the whole, teachers are faced with the task of teaching large numbers of children whose abilities and home support vary considerably, and of doing so not always with scientific training or ample resources in a society that lacks a clear consensus about what schools are for. The demands placed on teachers are enormous. They counter this situation by the way they themselves construe their task and the means they use to perform it. Confronted with uncertainties about subject matter, student behaviour and educational goals, teachers approach their work in ways that will make it less uncertain, thus accommodating to complex situations over which they have no control.

Issues for Deliberation

- Official documents acknowledge nontraditional topics and approaches with a "rhetoric of options." In practice, these approaches are often abandoned under pressure of time. If options are not exercised by teachers, how appropriate is the "core-plus-options" approach to curriculum policy making?

- Teachers who concentrate on inculcating good habits in students set social priorities ahead of the development of intellectual skills, such as the ability to think critically and exercise good judgement. Doubtless, the socialization of students is important, but given the complex role of science in our cultural and political lives, is the emphasis on socialization a wise priority?

- Teachers think that, for students and their parents, getting high grades is all-important. Teachers blame this attitude for their failure to engage students' interest in the subject. But with grades as their objective, how well do students understand what they are doing in the science classroom? Not knowing how knowledge is achieved in science, the social implications of the technology based on that knowledge or the cultural milieu of science, are not students in danger of seeing the isolated laws and facts they learn as no more than pieces in a unfinished jigsaw puzzle?

- How would teaching innovations affect the persistent problems of teachers, especially those who are not science specialists? What would it mean to teachers and students to take a more adventurous view of the subject? What teaching strategies could be used with nontraditional approaches to content? How would these methods be justified to parents and students? What would be the effect of such strategies on class control, motivation, evaluation and grade progression?

Conclusions: Future Directions

Practical problems, such as those in science education, are not resolved simply by collecting research data. As the reader will have noticed, research data raise as many questions as they answer. The resolution of problems in science education comes about through a process of deliberation in which the (possibly conflicting) values of the participants are as significant as the research findings.

The research findings summarized here played an important role in the deliberative conferences that constituted the final phase of the study. From those conferences flowed recommendations for change in science education policy and practice, based on participants' views of the problems confronting them. These conferences and recommendations have provided grist for Council's own deliberations and have contributed to the development of its Report on this subject. However, while Council can write a "final" report, the task of science education goes on. The questions raised by this research are too numerous and too complex for all of them to be resolved at this time. They are included here in the hope that deliberation will continue among all who are concerned for the scientific literacy of Canadians.

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