Report 36

Science for Every Student

Educating Canadians for Tomorrow's World

April 1984

Dr. Stuart L. Smith,
Chairman,
Science Council of Canada

Dear Dr. Smith:

On behalf of the Science and Education Committee, I take great pleasure in transmitting this report to you. For nearly four years, the committee has worked hard to meet the aims of the science education study that were approved by Council at its 75th meeting in May 1980, as follows:

- to establish a documented basis for describing the present purposes and general characteristics of science education in Canadian schools;
- to conduct an historical analysis of science education in Canada;
- to stimulate active deliberation concerning future options for science education in Canada.

From the outset, we sought and received the cooperation of the Council of Ministers of Education, Canada and the science teaching profession, without which the study could not have been conducted. To all these individuals and institutions that have been deeply involved in our work, we are most indebted.

Studying science education at both elementary and secondary levels, in a bilingual country, with 10 provinces and two territories each of which is autonomous in matters of education presented a unique challenge. In meeting this challenge, the committee adopted a strategy called "deliberative inquiry," developed by Dr. Graham Orpwood, one of the study's project officers. This strategy was designed to generate, over the duration of the study's activity:

- a continuing commitment to deliberation and change on the part of all those with an interest in science education;
- a reliable database about science education as it is, the context in which any proposed changes must occur;
- a range of issues and alternative courses of action on which to focus deliberation.

These three components set the pattern for phases 1 and 2 of the study, raising awareness of issues (phase 1) and research (phase 2). The two phases, which overlapped in time, resulted in the following publications:

- five issues of a newsletter;
- six discussion papers;
- two workshop proceedings (one of which, on the science education of women, also led to the publication of a statement of concern);
- a three-volume background study including: an analysis of science curriculum policies of all provinces and territories; an analysis of 33 science textbooks, using a team of 18 specially trained analysts; a survey of science teachers that received a 61 per cent response rate (over 4000 respondents); a series of eight case studies of science teaching involving a team of nine researchers in eight different schools in all parts of Canada.

The research program of the study was, in itself, a tremendous effort and represents one of the most comprehensive programs of original research in Canadian education. I feel that Council may be justifiably proud of this accomplishment for itself; indeed, the work has already begun to stimulate further research.

All this activity, however, was but preparation for the third and crucial phase of the study, the deliberative phase. For this phase, the research data were published as a three-volume interim report and distributed to more than 300 individuals who had indicated their commitment to deliberation about future directions for science education in their provinces and territories. These individuals brought their concerns for science education from all sorts of positions and perspectives: ministry officials, school administrators, teachers, university faculty, scientists, engineers, employers, trade unionists, parents and students were all represented at 11 deliberative conferences, which took place in the spring of 1983. The interim report served as a foundation for the discussions and was the background for the advice and recommendations that came forward.

I cannot overstress the importance that the committee has attached to this advice and these recommendations. The conclusions from the deliberative conferences gave the committee a sense of what those who have concerns for science education see needs to be done and, moreover, how they see that it may be done. In a very real sense, the deliberative conferences were the climax of the committee's work. When they were over, we felt extraordinarily well informed about science education in Canada and ready to prepare this report.

In transmitting the report to you, I wish to acknowledge the work of my colleagues on the committee, who have worked together in an open and cooperative spirit and who now are unanimous in their support of the report. From its formation until February 1982, the committee was chaired by Dr. H. Rocke Robertson and Council owes a great deal to Dr. Robertson for his wise guidance in the formative stages of the committee's work.

On behalf of the committee, I would also like to express appreciation to the project officers, Graham Orpwood and Jean-Pascal Souque, and to their research associates, Isme Alam and Janet Ferguson. Their teamwork and support of the committee's work has enabled the completion of what we believe to be a significant contribution to the country and its young people.

Yours sincerely,

Lawson Drake

E. Lawson Drake
Chairman,
Committee on Science and Education; and
Department of Biology,
University of Prince Edward Island,
Charlottetown, Prince Edward Island.

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Chapter 1

Science Education for Tomorrow's World

Tomorrow's citizens and decision makers are in school today—are they receiving the education they will need in the 1990s and beyond? As the rate of change increases and the world becomes ever more complex, Canadian students need more and better science education to prepare them for the future.

Renewal in science education is essential: that is the conclusion of a four-year study involving research and deliberation on science education undertaken by the Science Council of Canada. The study, which has produced one of the most comprehensive databases ever compiled in the field of Canadian education, had two main thrusts: to investigate the past and present place of science education in Canadian schools and to develop recommendations for its future directions.

The research program included the examination of science curriculum guidelines in each province and territory,[1] an analysis of 30 commonly used science textbooks, a survey of teacher opinion and eight case studies of science teaching in schools in various parts of the country. The results of this research are published as a three-volume background study, *Science Education in Canadian Schools.*

An interim report of this research was circulated to participants at 11 deliberative conferences attended by ministry[2] and school officials, teachers, parents, students, and representatives from universities, industry and labour. All concerned demonstrated an openness to change and a willingness to cooperate in searching for ways to improve our system of science education. The Science Council is confident that the needs and new directions identified at these conferences represent a consensus to which there is significant professional commitment.

The present report summarizes the results of all this work, particularly the conclusions of these deliberative conferences. The report is organized as follows:

- Why Study Science? (Chapter 2)
- Science Education Now (Chapters 3 and 4)
- Recommendations for Renewal (Chapters 5 and 6)

Why Study Science? (Chapter 2)

The Council believes that it is of national importance that all Canadians receive a quality education in science and technology. For Canada to cope with social changes rooted in highly specialized technologies, its citizens need the best *general* education possible — an education comprising not only the traditional basics of language and mathematics, but also the *new* basics of our contemporary culture: science and technology.

We therefore endorse the concept of "Science for All."* This does not mean ignoring individual differences among students. These must be understood, respected and provided for. Science for all means a first-class science education for every student: those in elementary schools as well as those in secondary schools; girls as well as boys; the most able students and those less able; those having special interests in science and scientific careers and those without these interests; students in all regions and provinces; francophones, anglophones, and those of native ancestry.

Not only must science education be provided for all students, the aims and content of school science programs must be appropriate to their needs. The Council believes that the goal of scientific literacy for all can be achieved through a balanced curriculum in which science is taught with four broad aims in mind:

- to encourage full participation in a technological society;
- to enable further study in science and technology;
- to facilitate entry to the world of work;
- to promote intellectual and moral development of individuals.

Consensus about these aims is important for two reasons. First, they provide a basis from which to examine present science programs. And second, they establish a backdrop against which recommendations for future change can be developed.

Science Education Now (Chapters 3 and 4)

The major findings of the study concern the serious gap between what science education is *supposed* to achieve and what it *actually* achieves. For example:

- science is rarely taught adequately (if at all) in elementary schools across the country;
- students enthusiastic about science and those achieving above-average marks complain about the lack of challenge in their schools;
- very little is being taught about the crucial interaction among science, technology and society;
- many girls still do not see scientific or technological careers as being relevant to them, and turn away from science; both Canada and half of its citizens are the losers;
- teachers complain about the lack or ineffectiveness of inservice programs for their own development;
- there are few openings for young people entering the teaching force, and older teachers have little incentive to innovate or strive for excellence.

* The American Association for the Advancement of Science and the National Science Teachers Association in the United States recently adopted the proposition that "Every child shall study science every day of every year." This is, of course, a statement of principle rather than a policy recommendation for education.

In addition, it was evident from the study's research that science is mostly taught with the aim of preparing students to study more science. Little evidence was found of teaching practices or textbooks designed to promote achievement of the other three important aims.

Recommendations for Renewal (Chapters 5 and 6)

In the light of its analysis of the present state of science education in our schools, the Council recommends eight major initiatives that are urgently required for the renewal of science education. These initiatives are summarized as follows:

Science Education for All
1. Guaranteeing science education in every elementary school
2. Increasing the participation of young women in science education
3. Challenging high achievers and science enthusiasts

Redirecting Science Education

4. Presenting a more authentic view of science
5. Emphasizing the science-technology-society connection
6. Setting science education in a Canadian context
7. Introducing technology education

Monitoring Science Education

8. Ensuring quality in science education

In addition to these general recommendations, the Council presents 47 specific recommendations designed to implement these initiatives. These specific recommendations are directed at ministries of education, school boards, schools, universities, teachers (and teachers' unions), textbook publishers, industry, the federal government and other national bodies.

The specific recommendations are concrete, realistic, and immediately applicable. Canadians must act on them *now* — any delay in renewing our science education systems threatens Canada's capacity to participate in a changing world. And Canadians must act *together* — the renewal of science education in Canada can only take place with the active support and cooperation of all: individuals, groups and governments. To make these things happen is the challenge today.

Chapter 2

Why Study Science?

Our research and deliberations suggest an emerging consensus about the aims of science education. In our judgement, Canada needs science education that can:

- develop citizens able to participate fully in the political and social choices facing a technological society;
- train those with a special interest in science and technology fields for further study;
- provide an appropriate preparation for the modern work world;
- stimulate intellectual and moral growth to help students develop into rational, autonomous individuals.

Science for the Informed Citizen

In an age of technology, this goal for science education must be among the most important. If we as a society fail to understand the interaction of science, technology and society, we surrender control of the most potent forces shaping our world to a technocratic elite. Council endorses the view, expressed in the 1972 UNESCO report, *Learning To Be*, which stated:

> An understanding of technology is vital in the modern world and must be part of everyone's basic education. Lack of understanding of technological methods makes one more and more dependent on others in daily life, narrows employment possibilities and increases the danger that the potentially harmful effects of the unrestrained application of technology — for example alienation of individuals or pollution — will finally become overwhelming. Most people benefit from technology passively, or submit to it, without understanding it. They cannot, therefore, control it. Education in technology at the conceptual level should enable everyone to understand the ways in which he can change his environment.[1]

There was international consensus on this point 12 years ago; yet little has happened, at least in North America.

We do not lack advice on this topic, however. In one of the discussion papers commissioned during this study, Glen Aikenhead calls for a "science and society curriculum [that] views science as a cultural phenomenon and within a social context."[2] In another, James Page echoes the conclusion of the Symons report, *To Know Ourselves*, that "Canadian school children learn virtually nothing about the accomplishment and impact of science in their own country."[3] In a third, Donald George points out that "even informed public debate is not possible because of the general indifference and ignorance about the nature of technology and its social effects."[4] The deliberative conferences held in each province were in general agreement with these views. The demand for science to be taught in such a way that students learn about science and technology and about their influence on contemporary Canadian society was just about unanimous.*

Science for Further Education

Science education in elementary and secondary schools is also an important preparation for further studies in science and other subjects. Historically, one of the major functions of schools has been to prepare students to enter university or college. Now, educators are beginning to broaden the meaning of postsecondary study to encompass lifelong learning, and consequently to ask what kind of preparation is appropriate for this.

Until recently, many people felt that learning science — usually physics, chemistry and biology — in the senior grades of high school was important only to those who intended to study those subjects at university. Accordingly, students whose interests or abilities were not oriented in this direction tended to take other subjects, leaving science to the "specialists." This trend was reinforced by new courses introduced in the 1960s and 1970s; these courses emphasized the structure of the discipline, addressed relatively advanced theoretical concepts, and were explicitly designed to increase the supply of trained scientists and engineers. In the 1980s, society still needs well-educated students to enter scientific programs at university, of course, but educators are no longer convinced that students are ideally prepared by the courses developed in the 1960s (largely in the US and adapted or imported for Canadian schools). These courses lack a social (and particularly a Canadian) context,[6,7] and also tend to overemphasize advanced theoretical concepts,[8] so that students who know nothing of the chemistry of domestic processes such as photography and cooking are taught about molecular orbitals. Ensuring excellence in the basic training of future scientists should not mean that students are subjected to abstractions they can scarcely comprehend or relate to their personal lives.

Education in school (including education in science) must be perceived as one part, albeit a special and intensive part, of a process of lifelong learning. Science education throughout the high school years should be a preparation and encouragement for students to learn about science throughout their lives.

Moreover, science studies in school should also be linked to other areas of study. A narrow focus on science as mainly for future scientists contributes to premature specialization and tends to isolate the various subject areas. The Science Council has received eloquent arguments favouring closer coordination between science and mathematics teaching,[9] science

* Many other countries are gradually shifting towards a "science-technology-society" (STS) orientation for science education.[5] Progress is particularly advanced in Europe and has gathered momentum in third world countries as well, as can be seen from recent international conferences on science education in which Canadians have been leading participants. This international climate is both stimulating and encouraging.

and social studies,[10] science and engineering,[11] science and the humanities.[12] We believe that all students, regardless of career aspirations, will benefit from such cross-linking of knowledge areas.

Finally, students should learn to question the basis of their own scientific knowledge. Science rests on assumptions about the nature of reality and about our ability to comprehend reality; these assumptions cannot be questioned from within the scientific framework. Several authors of our discussion papers suggest that developing students' ability to approach science critically can assist in broadening secondary school science courses and linking them with other parts of the curriculum. Aikenhead, for example, talks of "Science: A Way of Knowing";[13] Munby about "how we *hold* scientific knowledge";[14] and Nadeau and Désautels about a "valid concept of science."[15] The Council is convinced that such ideas can be the foundation of a broadly based science program that prepares students for a lifetime of learning and enables them to examine their own knowledge critically.

Science for the World of Work

Schools have always provided some sort of vocational or prevocational function. In practice, however, courses of an explicitly vocational nature have usually been designed for or relegated to students of lower academic ability; other students are steered towards academic courses leading to postsecondary education as the most appropriate preparation for entry into the workforce. Education for the world of work is important to society and to individuals: our economy needs appropriately trained human resources and individuals need employment that is financially and personally rewarding. If these needs are to be met, the Science Council believes that the relationship between secondary education (especially in science and technology) and the world of work must be radically rethought.

This rethinking should be based on the fact that technology will be a key factor in the future employment of large numbers of our present school children. These students must learn how technology affects the workplace, how it will influence the nature of work, and what new career opportunities it creates.

Students need this training for their own benefit. And society requires it, for among these students will be found the individuals who will be tomorrow's entrepreneurs and technical innovators. Indeed, the Science Council has often highlighted the importance of technological innovation in the development of Canadian industry and the critical role played by individual innovators.*

* For example, Guy Steed points out the "primary place of entrepreneurial individuals in successful technological innovation."[16] A blend of "judgement, grit, and sheer luck"[17] results in the juxtaposition of information "in the minds of imaginative people somewhere,"[18] and a new idea is born. From the creativity of individuals, industries and society prosper.

At issue for the present report is whether or not education in school can stimulate or contribute to the innovative capacity of individuals. On this subject, Marcel Risi, former commercial director of the Centre de recherche industrielle du Québec (CRIQ), offers a critical analysis of the goals and methods of contemporary education. He writes:

> Training young people who will have to confront a working environment evolving so rapidly that the knowledge they have acquired is frequently obsolete or no longer required is one of the challenges facing education.[19]

To meet this challenge, schools have traditionally taught ever more abstract concepts, the "big ideas" of science, rather than its concrete descriptive aspects. But Risi stresses that the real mistake is having students acquire knowledge *for its own sake*, without teaching why it should be acquired. He suggests that students should be given real problems and encouraged to seek and use information to develop innovative solutions. In such a system, Risi points out:

> Education, like industry, will become holistic. In corporations, for example, it is not enough to combine disciplines and find the "recipe"; rather the task is to learn to combine, integrate and prioritize information flowing from the real world.[20]

Clearly, the education he prescribes cannot be provided by traditional courses that focus on pure science, that is, on the discovery and acquisition of abstract knowledge. What he is suggesting is a shift towards an education that includes technology; here disciplinary knowledge is not simply gathered but is applied to achieve a desired end, perhaps the design of a useful process or product. For example, electronics and materials technology offer scope for students to design, construct and test products of social value. Experimental courses of this type have been developed in some countries but resistance is strong from the advocates of physics, chemistry and biology as the traditional basis of scientific education. As we look towards the future, can we limit students in grades 11 and 12 to a choice of physics, chemistry or biology, as is typically the case in Canada today? Will this narrow choice serve the broader needs of students and the Canadian economy?

In this new vision of education, emphasis shifts from the acquisition of information to its use. In the emerging information society, the difference between the skilled and the unskilled will be based not on what is known or not known but on how well knowledge is put to use. More and more, information is being stored in readily accessible form in computer data banks. The successful members of our society will be those who can draw upon this information and synthesize it to solve problems. Already, 40 per cent of Canadian workers are engaged in information-related occupations and this number continues to rise.[21] Education for the world of work must therefore increasingly stress the information-processing skills that the citizen of the future will require.

Science for Personal Development

Most of the subjects in the school curriculum are intended to contribute to the achievement of educational aims beyond the immediate one of learning the subject matter itself; and science is no exception. Educators give particular importance to the intellectual and moral development of the individual, that is, development of the mind, of rationality, an ability to think critically and so on. This view of the essential purpose of a liberal education dates back to the Greeks but its importance in contemporary society has been reiterated constantly during our deliberative conferences.

Intellectual development can be divided into two components: the acquisition of knowledge, the cumulative product of our culture's intellectual efforts, and the development of intellectual skills. The two cannot be divorced from each other. The inquiry processes of science have been analyzed in terms of the skills that a scientist exhibits when engaged in scientific inquiry. Because of this, many science educators have become preoccupied with helping students develop these process skills — observing, classifying, hypothesizing and so on. Although these skills are worthwhile, two caveats are in order. First, some educators tend to forget that scientists use these skills in solving real problems of which they possess considerable background understanding and not in a substantive vacuum. Scientific observation, for example, has as much to do with what is in the observer's head as with what is done with the eyes.[22] Second, science is not unique among the disciplines that use rational argument and critical thinking and therefore science education cannot be an exclusive vehicle for the development of these skills.[23] Although science should play an important role in a student's general education, it must play this role in harmony with education in the arts and humanities.

There are, however, contributions to a student's intellectual growth that only science can make. For science, though it shares certain features of rational thought with other fields, has a function and content that give it a significant place in our culture. Scientists study the physical environment and develop ideas that explain how things work. Similarly, in learning to cope with the world, young children develop their own explanations for phenomena, and these ideas enable them, more or less adequately, to understand and relate to their environment. Inasmuch as this activity parallels that of the scientist, at least in purpose, it is important for students to learn that they can understand and deal with the world by means of their own observations and constructed explanations, that all such explanatory frameworks have their limitations, and that science offers frameworks for explanation and control which, while also limited in scope, have been shown to possess particular explanatory power and which have thus become accepted by the scientific community and by society as a whole.

Thus, science education encompasses both processes and knowledge that can nurture a child's intellectual growth. Not surprisingly, the value of science education for a child's intellectual development has been promoted by such distinguished contributors to the psychology of cognitive development as Jean Piaget and David Ausubel. If science education is to be successful in achieving this goal, then instruction must start "where the child is," in terms of both skills and knowledge. This pedagogical principle has profound implications for the science curriculum and its implementation.

Scientific Literacy

Science education must be the basis for informed participation in a technological society, a part of a continuing process of education, a preparation for the world of work, and a means for students' personal development. The Science Council believes that these four aims of science education are vital for science programs in Canadian schools.

Furthermore, the Science Council believes that a balance among all of these aims should guide the development of science programs. Council supports a concept of scientific literacy that has a composite nature. As Roberts has described in his discussion paper, this is what the term has come to mean in much of the literature of science education.[24] If all students are to benefit from an education in science, then the science programs offered in schools must give substance to the full scope of the concept of scientific literacy outlined here. There is little point, for example, in justifying science education in schools on the basis that students need to understand the social impact of technological change if science courses do not respond to this need. An appropriate balance of all four aims for science education should therefore be evident at each level of schooling.

High-quality science education is required at all levels and for all individuals. Canada needs its most able students to be challenged and stimulated so that they succeed in science studies, but it also needs all its citizens to be scientifically literate. The Science Council is confident that these needs are not incompatible.

Chapter 3

The Context of Science Education

The teaching of science, like any other institutionalized activity, takes place within a variety of contexts, all of which influence both what is done and what can be done.

Three contexts are particularly important to the success of science education:

- the human dimension, the intellectual and social climate of the school and especially the relationships among students, teachers, and administrators;
- the physical dimension, the concrete facilities and equipment for science education, including textbooks; and
- the political dimension, the degree of public support and confidence in science education.

For example, when parents and school administrators place a premium on keeping students quiet and under complete control at all times, schools are likely to use didactic methods of science teaching rather than inquiry methods. As these two teaching methods are not merely alternative means to the same end but actually result in different outcomes, the context can affect which aims are achieved and which are not. Similarly, in schools in which textbooks and teaching omit any reference to the impact of science and technology in Canada, students are unlikely to learn much of such things. If school examinations measure only the students' acquisition of scientific information, the same emphasis will probably dominate the teaching. In short, student ability and teacher competence, though necessary, are not sufficient to assure the attainment of any set of aims for science teaching; the contexts of instruction are all important to the success of science education.

If improvements are to be effected in science education, then contextual factors must reinforce rather than resist any changes. Understanding these factors was therefore a major purpose of the research phase of the Science Council study. This chapter summarizes some of the background data collected by the study about the human, physical and political contexts of science education in Canada.

Human Context

The essence of all effective teaching, in science as in other subjects, is the relationship between teacher and student. Teachers who are bright, competent, excited by the subject matter, and sensitive to the needs of the students, are the ones who can work miracles even in the absence of ideal conditions for teaching. Correspondingly, teachers who are uncomfortable with their own background knowledge or who are demoralized because of the working conditions can negatively influence students' attitudes towards science.

If Canadian students are to become scientifically literate, then science teachers at all levels of the school system must be properly prepared to teach science and enthusiastic about participating in science teaching. The teachers themselves must be taught with the same scientific literacy in mind, they must be provided with the necessary pedagogical support and training and the management of schools must exert a positive influence on their attitudes towards their work. The Science Council study therefore gathered information about teacher preparation, inservice training and morale.

While most science teachers in Canada have university degrees and are committed to teaching, the extent to which they are adequately prepared for teaching science is problematic. Of those teaching science at the early-years level (grades 1-6, typically), more than two-thirds are university graduates, and this proportion is higher if one considers the younger teachers only.[1] However, over half of them have had no university-level mathematics and nearly three-quarters, no university-level science. In the middle years (grades 7-9, typically), the situation is better, though still not entirely satisfactory from the point of view of ensuring a quality science education; at this level, one-third of all science teachers have had no math or science since high school. Those who teach science in the senior years are relatively better qualified: 95 per cent have had at least some university science but often this training was received many years ago — more than 10 years in the case of over one-third of the teachers. Further analysis of teachers' science backgrounds is difficult because degree programs are described differently across the country and some provinces do not collect this information about teachers.

The Science Council also studied inservice training because many teachers of science have been teaching for a long time — over half for more than 10 years. Lengthy teaching experience can clearly have benefits for students' science education but it can also present problems if teachers become less able or willing to change traditional methods of teaching. For this reason, inservice education is important. At the moment, most teachers are very dissatisfied with the quality of the inservice educational programs provided for them. In our survey, at least two out of three described such programs as ineffective or nonexistent and this judgement was confirmed at each of our deliberative conferences. (It must be noted that inservice training is but one aspect of a larger problem currently facing educational authorities: managing an aging teaching force.)

The study also examined teacher morale and found that very few secondary school science teachers would prefer *not* to teach science: only 1 out of 10 in the middle years and 2 out of 10 in the senior years. Those planning to continue their teaching career, however, often face a rather gloomy prospect. Several confided in us, during the deliberative conferences, that their morale was very low. They cited several causes —

discipline problems, low expectations of the school system and the phenomenon of "bumping." Bumping is a system, incorporated in many collective agreements with teachers' unions, in which protection from layoffs is strictly by seniority; when enrolments fall, less experienced teachers have to give up their positions to their more senior colleagues with no consideration for the younger teachers' qualifications, their enthusiasm or the quality of their work. The following extract from the case study of the École Lavoisier illustrates this phenomenon.

> Every teacher is quite powerless either to halt the process or to have recourse from it. Only the most senior (with over 17 years' seniority at present) are spared. But even they, like the students, suffer the very serious effects of the process on the atmosphere of the school: fear, suspicion, confrontation, discouragement — all of which profoundly affect school life, not only from April to the end of the school year, but to some extent throughout the year. Protests have been lodged with all the authorities. Everyone considers "bumping" to be the worst calamity with which teachers are faced, the biggest cause of lack of commitment and lethargy. Neither teachers nor administrators can do anything to halt the implacable machine. Even if they are not directly affected, they all suffer the fallout. One teacher told me, "Just try to talk about education in May. All anyone talks about is bumping, and it's understandable."[2]

The Council believes that the deployment and layoff of teachers based solely on the seniority principle fails to acknowledge the merit of excellent teaching and prevents the introduction of innovative ideas by younger teachers. Change in this area is urgently required.

Science education is strongly influenced, not just by classroom teachers but also by the educators who develop science programs at the ministry level and those who implement them at school board levels. These individuals, frequently former science teachers, hold senior positions for which, very often, no training and little support is provided. Given the broad scope of their responsibilities, these consultants are valuable and important to the ultimate success of science education in each province. Despite this, they often appear to be insufficiently appreciated by teachers and by the administrative hierarchies of ministries and school boards.

Physical Context

In the physical context, the study looked at special facilities and equipment for science education, textbooks and computer aids.

Special facilities and equipment let students enjoy first-hand experiences of science. The need for an appropriate physical context was recognized in the reform movement of 20 years ago and is still considered important, except that the definition of what is appropriate must be adapted to the changing aims of the science program. If students are to acquire a greater awareness of the technological culture of the present day, they need, for example, access to a computer at all levels of school. In addition, if students are to understand the impact of science and technology on society, they must learn about it through trips outside the school and via video technology in the classroom. As a participant at one deliberative conference expressed it: "Science and technology are all around the school in the daily lives of the students and their families." The school walls must not function to keep the real world of science and technology out and a pale shadow of it in.

Our survey shows that secondary schools usually have adequate facilities for science teaching, except for very small schools in remote areas; the same is not usually the case for elementary schools. In the senior years of high school, three teachers out of four have at their disposal a regular laboratory and suitable equipment; furthermore, they consider the quality of these to be good and sometimes excellent. At the elementary level, however, fewer than one in five have even occasional access to a science room. This situation places a major constraint on science teaching.

Science textbooks also form part of the physical context of science education. Despite predictions to the contrary, science textbooks are still of major importance in Canadian schools: 90 per cent of students use them and 80 per cent of their teachers plan lessons from them. On the whole, teachers seem satisfied with the available textbooks, although they point out that these textbooks have little attraction for the less able students.

Textbooks are bought by school boards from lists of publications approved by ministries of education. Only Québec and Ontario (and, to a limited extent, British Columbia) have a large enough school population to permit some degree of competition among publishers and to justify economically the creation of textbooks that follow the aims and program content of specific provincial science courses. In fact, nearly all the textbook publishers are located in Toronto and Montréal. One of the consequences of the limited market in smaller provinces is that, even where innovative curricula have been developed, it is often impossible to find appropriate textbooks. The same problem arises for French-language publishers seeking to serve the francophone populations in most provinces. As a result, publishers provide textbooks that have the greatest likelihood of being accepted everywhere, even if this involves making local modifications and negotiating for a monopoly with the ministry of education. The high degree of uniformity (among the provinces) in science content makes this process easier. Although provincial autonomy in theory permits the development of a completely original curriculum, the practice is severely limited, especially in smaller provinces, because of the inability of publishers to produce curriculum materials for small markets.

Closely linked to this problem is that of the presence of American books in Canadian schools. Even though scientific knowledge is international in nature, this is not so for scientific activity nor for science education. Science education in Canadian elementary schools mostly uses American books, especially the very popular *Space, Time, Energy, Matter (STEM)* series and its translated version *Les chemins de la science*. At the middle or junior high level, a significant number of Canadian textbooks have been introduced across Canada since Ontario published its new curriculum guideline for that level in 1978, thus demonstrating the effect that one large province can have on the national market. In the senior years of high school, particularly outside Ontario, American textbooks are used in considerable quantities. At this level, the market is fragmented by the existence of several separate science courses and by the lower enrolments in each optional course.

It is difficult to assess the extent to which science education is being influenced by the use of information technologies, and in particular the use of the computer. The situation is changing so rapidly that reports tend to be out of date almost as soon as they are written. It would appear, however, that appropriate hardware is available and being purchased by school systems at an ever-increasing rate; however, educational software is not always available, especially programs systematically related to the objectives of school science courses. The scarcity of suitable software, in our view, may soon push schools into purchasing imported software whose objectives may not be at all related to those of the provincial authorities.

Political Context

The third context of importance to science education is the political one. School boards and ministries of education function within a democratic system in which the public's expectations and demands have a real impact. Factors of specific importance in the political context of science education are the public's beliefs about science and technology and their importance, about the quality and effectiveness of schools, and about the relation of education to people's social and material wellbeing.

During the deliberative conferences, some of the participants mentioned the mistrust that a good proportion of the country feels towards scientific and technological activity. This attitude derives in part from the ignorance that prevails about the role of science and technology in this country. Better science education is one means of providing a sound basis for individuals to develop new attitudes.

The parents who participated in the deliberative conferences saw clearly the advantages their children can gain from a high-quality science education. Although they support the overall improvements of the school system, and of science education in particular, they still see a need to continue monitoring the performance of the education system. They want to know that their investment in education is being spent effectively.

Students, too, are taking their education seriously, although they sometimes wonder if society has a role for them to play. Industry, which is directly affected by the quality of the training its labour force receives, is willing to help in changing science education. The trade unions, facing problems such as health and safety at work and technological change in industry, are also very concerned about the scientific training that their present and future members receive. The universities and community colleges, for their part, have in no way lessened their expectations of science education. And finally governments, to uphold the scientific and industrial policies they have announced in recent years, realize they must help the public become more aware of science and technology and are beginning to take steps in this direction. Circumstances seem therefore to be coming together to build up popular support for science education.

Chapter 4

Present Directions in Science Education

Science for All?

A scientific education must be accessible to all and adapted to the needs of all. Despite the policies of ministries of education, we believe that certain groups do not receive the high-quality science education to which they are entitled.

Young children, being naturally curious about the world around them, can readily be taught science. Furthermore, if science is begun early in school, students acquire a good foundation and recognize its importance. Therefore the quality of science education in elementary schools is of vital importance. Unfortunately, it is at this level that the shortcomings of the system are most apparent. Information gathered at each of the provincial conferences tells the same story: very little science — and often, none at all—is taught in Canada's elementary schools.

Data from our survey had already pointed to difficulties at this level. Only three teachers out of five now teaching science wish to continue doing so. Nearly three-quarters of all early-years teachers have received no university-level education in science and over half have not taken courses in mathematics. Only one class out of five in the primary levels has specific facilities and equipment for science teaching. Thus, at the elementary level at least, many Canadian children are not receiving an adequate scientific education. Council strongly deplores that this is so.

The low emphasis on science in elementary schools also exacerbates another problem — the tendency for girls to opt out of science, especially physical science, as soon as they are permitted to do so. Perhaps many girls do not perceive science as being relevant to themselves because elementary school teachers, who are usually women, give science less priority. Certainly, girls do not participate in science courses in the same proportion as boys; consequently few women work as scientists in teaching, industry and the public sector in Canada. Because women are a minority in the scientific professions, they have less opportunity to participate in decision-making concerning the direction or rate of technological change. In a world shaped by science and technology, Canada can no longer afford to shrug off the underrepresentation of girls in science classes in secondary schools.[1]

Some people maintain that there are genetic causes for the differences in intellectual orientation between boys and girls, and that these differences prevent girls from excelling at science. Although this theory is not supported by any convincing evidence, it has received ample publicity that may indeed have influenced parents and teachers. The Science Council, however, finds the theory entirely inadequate to account for the large disparity in participation rates.

In the Council's view, it is more likely that societal attitudes are responsible. The cultural and moral values transmitted by parents to their daughters from the earliest age tend to turn them away from science and technology. Such common actions as giving construction kits to boys but dolls to girls reinforce this attitude, and the reinforcement continues through the school system. Over the years, parents, teachers, guidance counsellors, curriculum developers and policymakers unwittingly contribute to discouraging girls from studying science and engineering and restricting their career opportunities.

Another problem documented in the Science Council's study was the difficulty of providing a quality science education to francophones in many parts of Canada. Teaching science effectively in French outside Québec is an act of some heroism. Provinces with francophone minorities encounter considerable difficulties in obtaining science teaching materials in French and in recruiting French-speaking science teachers. (Moreover, the popularity of immersion programs is increasing the demand for elementary science classes in French, and therefore the problem is affecting an increasing number of students.) Council regrets the lack of resources that prevents francophone minorities from enjoying universal access to high-quality science education throughout their years in school.

Finally, at each deliberative conference, Council heard of the lack of challenge that science education offers to students who tend to be high achievers. Students who participated in the conferences emphasized this point and in some provinces the question provoked vigorous discussion. Council considers that science education should respond to the needs of all students, whatever their aptitudes or interests, and science education should also prevent both the most enthusiastic and the least interested from dropping out. This ideal has yet to be realized.

Researching the Science Curriculum

Describing the aims and objectives of school science programs is complicated by the fact that evidence collected at different levels can lead to a corresponding variety of conclusions. At one level, the evidence consists of the program, courses of study or curriculum guidelines prescribed by ministries of education; these define the *intended* curriculum. At a second level, school boards, schools and teachers create the *planned* curriculum through local programs and lesson plans. Thirdly, evidence from the classroom itself indicates the *taught* curriculum, which students actually experience. And finally, there is the *learned* curriculum, the students' intellectual and practical achievements. In an ideal world, of course, examination of all four levels would yield identical information. However, common sense suggests that this is never the case, and the study confirms this reality. Evidence from several levels was sifted to build up a comprehensive account of the state of science education in Canada.

At the beginning of the study, the Council of Ministers of Education agreed to cooperate with the Science Council on condition that student assessment *not* be a component of the study, an activity they considered to be a provincial prerogative. Thus, the Science Council could not describe the *learned* curriculum; we did, however, conduct four research projects to amass evidence concerning the other three levels.[2] We examined curriculum policies (guidelines) from every ministry of education for science programs at all levels to identify clearly the *intended* aims of science programs. We surveyed nearly 7000 science teachers throughout Canada to determine their priorities in planning courses and we reviewed the prefaces of science textbooks to determine the intentions of their authors; these projects yielded information about the *planned* curriculum. Finally, we made a detailed analysis of the contents of more than 30 of the most commonly used textbooks, and carried out a series of eight case studies of science teaching in schools in various parts of the country; this work provided important evidence about the orientation of the *taught* curriculum. And although we cannot infer that students learn what they are taught, we can reasonably assume that they are unlikely to learn what they are not taught.

After we collected the documented evidence, we undertook two stages of validation. Draft reports were submitted to ministries of education for comment and, in the light of their advice, inaccuracies of fact and interpretation were corrected. Then the reports were distributed to invited groups of individuals (more than 300 in all) in every province and territory. These included science teachers and officials within each provincial school system, representatives of the scientific community, both academic and industrial, representatives of labour and business, parents and students. Deliberative conferences were conducted in every province to permit these individuals to reflect critically on the present orientation of science education. Both the documented research and the views expressed at these conferences provided the basis for the Council's conclusions about the present progress of science education towards the goals outlined in Chapter 2.

Ministry Curriculum Guidelines

All of the aims for science education identified in Chapter 2 can be found in statements of ministry policy. In most cases, curriculum guidelines contain long lists of aims (up to 15 in some instances) with little comment on their relative priority. The analysis of curriculum guidelines shows that all the provinces consider that learning science content and scientific method are essential objectives. In regard to the latter, the so-called process skills — observing, hypothesizing and so on — are often set out in the same form as learning objectives for elementary and secondary schools. Rarely is a hierarchy of skills cross-referenced to different grades, ages or developmental levels.[3] Yet one might expect that a student undertaking the study of, say, physics at grade 11 would have acquired at least the basic skills of scientific methodology at an earlier level. And although official guidelines often mention objectives for personal development, they are silent about how teachers could ascertain whether critical judgement, creative imagination or awareness of a citizen's responsibilities have been acquired by students. The same is true, in general, for all the goals stated in ministry guidelines.

We noticed also that most provinces recommend objectives concerned with the science-technology-society interaction in the middle years. The importance of this focus at all levels was also agreed on in all the deliberative conferences.

The aims for science education (Chapter 2) include making students aware of the world of work and of the role of science and technology. Already, provincial school systems are showing a growing interest in applied science and engineering, including computer technology. Possibly some of this interest is derived from the economic crisis and the popularity of slogans like "planning for the information society." Whatever the stimulus, this interest is being translated into objectives that will take concrete form in the years to come. However, in view of the delay in developing curriculum resources to reach existing objectives, the feasibility of tackling new objectives related to the renewal of education is problematic. Even now, the provinces have very few goals related to career preparation. Although secondary school is primarily intended to provide a general education for all students, no one can deny that it also has a role to play in making students aware of careers in science and technology and of the impact of technology in the workplace.

Teachers: Their Priorities and Effectiveness

In our survey, teachers were asked to assign priorities to 14 different objectives for science education. Although official guidelines give no priority for these objectives, teachers do in fact choose what they consider most important to teach. The results of this survey give a good idea — at least at the level of the planned curriculum — of the priorities of teachers and how these differ according to the teaching level.

In elementary schools and in the first years of high school, the development of scientific skills and attitudes and of social skills are top priorities; the acquisition of scientific content occupies only sixth or seventh position. In the later years of high school, however, teachers give first place to the learning of scientific content. In general, teachers in elementary schools concentrate on a smaller number of objectives than their colleagues in secondary schools who, particularly in the senior years, tend to consider all objectives as being important.

The survey data also raised additional questions. In secondary schools, although 9 teachers out of 10 agree on the need to understand the role and importance of science in today's society, only half of them favour learning about scientific activity in Canada. Similarly, although teachers claim to be interested by the practical applications of science, they are not keen to know about the nature of technology or engineering. Apparently the here-and-now of science is given little importance in Canadian schools.

Teachers also rated their own effectiveness in attaining the objectives of science education. Not surprisingly, the objectives the teachers favoured were usually the ones they claimed to attain. There are exceptions, however, two of which concern the development of informed citizens. The objective concerning science in society is rated important by 9 teachers out of 10 but only 6 out of 10 consider they achieve this objective effectively. The same is true for the objective of developing the skills related to reading and understanding science-related materials. Finally, the development of social skills, which is considered important by 93 per cent of teachers in the first years of high school, is claimed to be attained effectively by only 65 per cent of them.

Teachers therefore recognize the importance of making room for the social dimension of science as well as its practical applications. However, they do not all wish to become involved in questions linked to the Canadian aspects of science and technology and they show little interest in setting science in a historical perspective. The interviews we held with teachers show that the argument they raise most often for staying within familiar boundaries is time: time to cover the program, time needed for discipline in the class, time spent on correcting and marking. Another argument is their own lack of training or professional development. According to teachers, their priorities are also shaped by a range of administrative constraints and a tradition of school management. These influences are directed almost exclusively towards two categories of goals for science education: personal development and preparation for further education. Aims concerned with developing informed citizens or preparing students for the world of work are given correspondingly lower priority.

Textbooks

At the elementary level, teachers find books in the school library the most useful resource for preparing lessons. In secondary schools, teachers also prefer to plan their courses around science textbooks — and not only those authorized by the ministries of education. How well do these textbooks reflect the objectives of the ministries of education, and are textbook priorities the same as those of the teachers? We analyzed the *stated* objectives in a sample of science textbooks and found that the books are directed mainly towards two ministry objectives: learning science content and acquiring scientific skills. We also found some textbooks that were concerned with the science-technology-society interaction. These books are mostly new, intended for the first years of high school, and often have Canadian authors. In books such as *ALCHEM* and *Scienceways*, everyday problems are integrated with scientific content. On the other hand, older textbooks, particularly those used in the later years of high school, do not discuss science-technology-society interactions. These books, such as the *Physical Science Study Committee* (*PSSC*) and *CHEMStudy*, use an approach based on the nature of science and its methods. The organization of these textbooks, therefore, follows the structure of each scientific discipline.

How do science textbooks and laboratory manuals assist the attainment of the objectives of science education? One way is by suggesting a whole series of experiments to train students in scientific method and let them "rediscover" or "verify" accepted scientific laws and relationships. The problem is that, in the majority of cases, neither the scientific question, nor the design of the experiment, nor the application of the results are matters for class discussion. Instead, students are locked firmly, from the beginning to the end of a laboratory session, in a predetermined step-by-step procedure. By following directions in a laboratory manual, they learn to do what is expected of them, not to experience the real scientific method.

Where the science-technology-society interaction is present in textbooks, it often appears in the form of implicit messages transmitted to the reader. Because these textbooks are relatively recent, they mostly reflect the attitudes that prevailed in the 1970s: for example, concerns over pollution and the waste of natural resources. The student learns that science and technology are responsible for these but learns little about how science and technology can also be used to rectify such situations or about the benefits that society gains from the intelligent use of scientific and technological knowledge. According to textbooks, any benefits from science and technology come almost exclusively from medical research. Few textbooks on physical science or general science refer to information technology or telecommunications, although these have been transforming our society for the last 20 years. These books also lack information about scientific careers and the world of work.

Students and the Classroom

The Science Council conducted case studies in science education in eight Canadian schools. This experience let us compare the intentions and priorities as stated by ministries, teachers and textbooks with what really happens in the classroom.

At the elementary level, we found a wide gap between ministry intentions and classroom practice. Few Canadian elementary schools offer science teaching during a prescribed period, by a confident teacher, and with the support of adequate facilities. When science *is* taught at the elementary level, it is mostly done in an integrated fashion. That is to say, by reading a book about science or by introducing scientific or technological aspects of a theme subject (like "water") and trying to respond to the interests of the students.

In the junior high school years, science teachers are constrained by the limited time available for covering the subject matter and also by the energy they spend on discipline and on encouraging good work habits in their students. Thus, content is given priority over all the other science education objectives. Science at this level is often presented as a catalogue of facts for the students to assimilate as quickly as possible.

In the senior years of high school, the case study researchers found that time constraints remain a crucial factor. The quantitative aspect of science occupies much of the time available. The "right answer" counts most and therefore, answering the questions in the "right" way takes precedence over inquiries into the real meaning of problems. Concern for students' own interests, which does occur in elementary science education, is lost in the senior years of high school.

Of the four goals for science education outlined earlier, three appear at the level of planning: personal development, preparation for further education and the development of informed citizens. At the level of teaching, however, it is the second of these that, more or less by itself, justifies the existence of science education. Although the idea of learning scientific skills is popular, teachers do not have any way of assessing whether science teaching really helps students become more scientific, show more critical thinking or exhibit more creativity. Similarly, although teachers want to develop enlightened citizens, the textbooks explain the science-technology-society interaction by giving examples like waste and pollution. These topics are afterthoughts, tacked on to traditional science teaching to be included if time permits. At the very time when young people are facing entry into a tough job market, the scientific training they are receiving does little to prepare them for transition to a work world permeated by science and technology.

Chapter 5

Conclusions and Recommendations

The Council is persuaded that there has never been a more opportune time for the renewal of science education in Canada. Moreover, this renewal can and should build on existing strengths and successes wherever these are found. During the course of the study, we saw many examples of dedicated, innovative and successful science teaching, curriculum development and teacher education (to note but three areas of science education) in every province and territory of the country. These must be recognized and acknowledged, both for their own sake and also as the basis for future growth.

Alongside these encouraging signs, we also found some problems. Based on the study findings, Council has identified eight ways in which the renewal of science education can be initiated. These can be divided into three groups as follows.

Science Education for All

1. Guaranteeing science education in every elementary school
2. Increasing the participation of young women in science education
3. Challenging high achievers and science enthusiasts

Redirecting Science Education

4. Presenting a more authentic view of science
5. Emphasizing the science-technology-society connection
6. Setting science education in a Canadian context
7. Introducing technology education

Monitoring Science Education

8. Ensuring quality in science education

In this chapter, each of these general recommendations is described to summarize the position of the Science Council. In Chapter 6 we discuss how they may be implemented.

1. Guaranteeing Science Education in Every Elementary School

> Science education should be provided for all children in elementary schools in Canada. It is already written policy. Now it must be put into practice.

Most children from kindergarten to the end of elementary school only receive a token education in science — despite the policies of every ministry of education. There is an attitude of resignation about this in the schools. Teachers emphasize the subjects they believe to be essential — language arts and mathematics — sometimes spending more time on these than is actually prescribed. Certain subjects, such as physical education, are given specific facilities and time periods and they therefore use the time that is allotted to them. But science is not considered essential; it is not taught by specialists nor is it given special facilities or scheduling; it is therefore relegated to a secondary position. In view of the new scientific and technological skills that society demands of its members today, Council believes that, although the use of specialist teachers in science may not be appropriate at this level, the low status of science education in elementary schools is unacceptable.

Much needs to be done to improve the situation: training for teachers who have no scientific background; support for those who do teach some science; provision of adequate supplies and facilities; preparation of appropriate curriculum materials. It should be possible to identify the elementary schools where high-quality science education is already being offered and take advantage of the expertise that has been developed there.

Teachers often claim that science is "integrated" into other class activities. In some cases, this approach involves using themes from reading textbooks, about pets for example, in order to get scientific information across to the children. The idea of integration is so vague, however, that it can only be determined by close classroom observation and by interviews with teachers who say they use this method. The Conseil supérieur de l'éducation du Québec has complained about the position of science education in that province's elementary schools and has recommended integration as a corrective step,[1] while admitting the impossibility of knowing exactly what each person means by "integration." Today integration stands more for the *ideal* of an interdisciplinary approach than a truly practical and applicable solution. Council believes that, in the short term at least, specific attention should be paid to science as such and that it should be offered to all students in elementary schools.

Most provinces already state that about 10 per cent of the time in grades 1–6 should be spent on science. The Council considers that more than this proportion can readily be justified, but at the moment many elementary schools do not provide even the prescribed amount of time. Elementary school principals can show leadership in this area, in particular by ensuring that all classes use the time alloted for science. Also, parents must demand science education for their children. Some will argue that more time for science means less time for other subjects such as language arts and mathematics or a lengthening of the school day. This argument has merit but students also suffer if the curriculum is unbalanced — that is, if it lacks an adequate scientific component. In the short term, Council believes science should be offered in every elementary school class to some degree. In the longer term, we recommend an increase to 15 per cent of class time for science in all provinces, after the implications of doing this have been studied fully.

Recognition must also be given to the vital contributions of those men and women who have resisted current trends and devoted their energies to improving the quality of science education at the elementary level. Some of these teachers help their colleagues in schools (but this seems to be rare); others write articles for the publications of science teachers' associations; still others help by ensuring that the scientific resources in a school district are available to all the teachers. Changes in science education should build on these efforts and take advantage of this enthusiasm.

2. Increasing the Participation of Young Women in Science Education

Measures should be taken by educators to ensure that girls have improved opportunities and greater encouragement to participate fully in science and technology education.

We have already noted with concern the low participation of girls in physical science courses in school and the negative consequences of this for their opportunities to pursue scientific and technological careers. The effects of the home environment on girls' attitudes towards science, towards themselves and towards future careers are obviously very important and parents who understand these influences can do much to shape their daughters' attitudes. It is therefore important to increase such parental understanding.

However, schools must play their part too. We reject the view that low participation is natural and therefore not a matter of concern. The question is not whether the schools should try to effect a difference but how such a difference can be made. Three areas appear to offer particular promise: the curriculum, teaching methods and career counselling. Each of these is discussed below in general terms and specific suggestions for implementing changes are outlined in the following chapter.

The Curriculum

Students bring to school a wide variety of experiences and these, in turn, affect what they learn from the school curriculum. Girls' experiences, unfortunately, are usually not those that the science curriculum takes for granted. Many girls lack the practical, mechanical experiences that are commonplace in the lives of boys. One study, for example, showed that 78 per cent of 11-year-old girls had rarely used tools such as screwdrivers (compared with 45 per cent of boys of the same age).[2] Without this kind of formative experience, it is difficult to understand some of the terms and concepts with which science lessons are constructed — terms such as vertical, force, angle, and speed. When science curricula for the early years are developed, the nature and quality of preschool experiences need to be taken into account.

Girls must be able to identify with science and technology as much as boys, and herein lies a practical dilemma. On the one hand, the teacher does not want to give the impression to students that there are two versions of science, one for girls and another for boys. At the same time, the teacher needs to avoid choosing examples, for instance of the applications of science, that reflect and reinforce male stereotypes and experiences. Teachers and textbook authors need to monitor their own practices carefully to ensure that a balance is maintained. The implementation of a science-technology-society emphasis in science education will likely make science more attractive to girls because it will stress its human aspects — that science is an activity involving people and affecting people in their daily lives.

This emphasis suggests a third way in which the curriculum can be structured to make science more attractive to girls, namely by including material on women scientists. Most books about great scientists throughout history are about men, with the exception perhaps of a reference to Marie Curie. Making available accounts of the work of women scientists and inventors, particularly Canadians such as Ursula Franklin, Thérèse Gouin Décarie and Helen Sawyer Hogg, can help girls see the potential of a scientific career.

Teaching Methods
Although most teachers nowadays avoid the most overt sexist practices of the past, subtle messages are conveyed to girls about what they are expected to achieve in science. One study, for example, showed science classes in which boys and girls worked in a laboratory in mixed pairs; the boys manipulated the equipment and took measurements while the girls read the instructions and recorded results. In another, student teachers addressed most of their questions to boys. Such practices, even though they may be unnoticed and unintentional, make girls feel peripheral and uninvolved in science classes. Teachers need to be made aware of the possible unintended side effects of their classroom behaviour. This behaviour includes both what is done (as in the second example) and what is not done (as in the first).

Career Counselling
Many students in school have only vague and often inaccurate ideas about what scientists and engineers actually do. In fact (as we learned by analyzing textbooks), some misconceptions can originate in science classes. Students need better information. In particular, girls need to be made aware of the need to plan a career and of the career opportunities in science and technology. In England, one program has brought female scientists and engineers into the classroom to teach lessons about science concepts that are used in their own work. This program has been popular with both male and female teachers and students. To create a classroom climate in which girls' interest and achievements in science are encouraged requires commitment to change by both parents and educators.

3. Challenging High Achievers and Science Enthusiasts

> Students with a high ability or special interest in science and technology should have program provisions made to encourage and challenge them to further inquiry.

Some students need more challenge to reach their full potential in science education. These students do well in school, both in science and in other subjects, but the present educational system does not offer them enough challenge. Although school systems have been setting up various programs aimed at groups with special needs in the last few years, high-achieving students have often been neglected — perhaps because they are considered to have a built-in advantage. Council greatly regrets this neglect, which jeopardizes one of the most valuable Canadian human resources.

Some students, although they do not necessarily belong to the group of generally high achievers, do have a special interest in science and technology. This interest is revealed by involvement in extracurricular science activities, an interest in keeping up-to-date with developments in science and technology, or simply the wish to do more science in school. Council believes that these students also should have a stimulating and instructive experience of science, which encourages them to further inquiry. For this, school systems should develop science enrichment programs or, where conditions are appropriate, special schools in which science and technology subjects are particularly featured within a general education program.

4. Presenting a More Authentic View of Science

The view of science and technology presented to students should include historical, social and philosophical dimensions.

The Science Council is concerned with the image of science conveyed by science textbooks. Research has shown that "textbook science" tends to be overly standardized and simplified in order to present a smooth road to scientific knowledge. But if science itself is a search for explanation, then surely science education must give students an authentic explanation of the way science works.[3] The Council acknowledges, in general, the accuracy of the scientific knowledge contained in textbooks and has received few complaints about that. The problem lies with the inadequate representation of the scientific enterprise and the consequences of this for students.

A better portrait of science, we believe, should include the following aspects: the history of science and technology, an account of their relationship, and a reflection on the nature of scientific knowledge.

The history of science and technology, particularly that of Canada, will show students how the social and political climate can determine whether scientific activity is valued or ignored, and whether the results of research are well used. Students should also learn about the constant interplay of science with technology, the latter being not just the application of science but also a source of scientific problems and a practical key to scientific advances. In this country, our scientific tradition owes much to early achievement in fields such as geology and agriculture and to the contribution of engineers in several areas. Council expects science education to give a fair account of the role of technology in the development of science. Finally, reflection on the nature of scientific knowledge will make students aware of the limits of science. Although Council does not expect children or adolescents to be trained in the philosophy of science, it does expect science educators to be trained in this area, so that the science they teach will more closely resemble the science that is practised in our contemporary society.

This more authentic account of science will benefit future scientists, engineers and technicians by giving them a realistic view of their future activities and a necessary awareness of how such activities are influenced by the social and political system. Future citizens, also, will have more realistic expectations of science and technology and will be able to base their political and social decisions on a sound knowledge of how science and technology function.

Finally, the history of science provides opportunities to reflect on scientific knowledge; more importantly, it promotes values such as a respect for knowledge, humility, perseverance, cooperation, critical judgement and striving for excellence. These are values to which both the Science Council and the education system are firmly committed.

5. Emphasizing the Science-Technology-Society Connection

> Science should be taught at all levels of school with an emphasis and focus on the relationships of science, technology, and society in order to increase the scientific literacy of all citizens.

Objectives of this type appear in the curriculum guides of all ministries of education but for the most part, little importance is given to them by teachers, textbook authors and other science educators. The Science Council strongly believes that our future citizens need to understand science and technology and the impact of both of these on society. Accordingly, the Science Council regards this objective as an essential goal for science teaching in schools, and a matter of top priority at all levels of schooling.

In the earliest years of school (up to grades 6 or 7), this objective should be one of the most important because students are beginning to encounter science and technology in their own lives. At this time teaching about science and technology should make maximum use of the children's innate curiosity about the world around them - both the natural, physical world and the constructed technological one. Special attention at this stage should be paid to the immediate environment of the student, be that northern, rural, coastal or urban.

In the middle years of schooling, the teaching of science content becomes more systematic; students can then be offered a more detailed understanding of the science-technology-society interaction. At this stage, they can be made aware that scientific and technological activities give rise to choices; and making these choices involves value decisions on a personal and a societal level. Teachers can encourage discussions about decisions and choices that the students encounter in daily life, such as environmental conservation and the wise use of energy.

In the senior years, students are beginning to be more aware of public issues with scientific and technological components and of the political choices that must be made in relation to them. Also, they can begin to understand more clearly the different functions and uses of science as a way of knowing, and of technology as a means of achieving desired ends. Both life science and physical science can be taught with an emphasis on science, technology and society, and students must be made aware that objectives in this area are as important as those concerned with learning science content or acquiring scientific skills.

This emphasis for science education is not the only important one. Students also need to develop scientific skills and learn about the nature of science. Teachers, however, cannot emphasize many things at the same time. Often, only the science content is really stressed. Teachers and curriculum planners therefore need to make conscious decisions concerning which units of a science course should be taught with one emphasis and which with another. Clearly some scientific topics lend themselves particularly well to certain emphases. For example, energy and genetics are topics that should be presented with a science-technology-society emphasis at least once during a student's scientific education.

In speaking of emphasis, we do not mean something to be taught instead of a science topic, nor something to be added on after the "real" science topic is finished like the "applications" sections of some textbook chapters (which are often ignored). Emphasis implies a particular way of teaching the whole of a given science topic. For example, an understanding of the techniques used for separating mixtures of substances can be readily acquired by studying commercial processes such as oil refining and water purification. The byproduct of such an emphasis in the teaching materials is that students also learn how scientific techniques are used industrially. Curricula and textbooks are preoccupied with emphases concerning the development of science-related skills and concerning the nature of the scientific discipline. We are recommending here that these emphases be brought into balance with the science-technology-society one for the sake of promoting the general aim of "science for the informed citizen."

In regard to the question of what proportion of a science course should contain an emphasis on science, technology and society, we make the following suggestions as a guide to curriculum committees and teachers:

Early years (to grade 6):	50 per cent
Middle years (grades 7-9):	33 per cent
Senior years (grades 10-12):	25 per cent

Such a rebalancing of science programs will require changes to be made in ministry curriculum guidelines, in teachers' training, in textbooks and other curriculum resources, in teaching methods, and in evaluation strategies. Most of all, it will require the approval and commitment of all those inside and outside the schools who together are the stakeholders in science education and who can influence what takes place in science classrooms. There are promising beginnings in several parts of Canada. Science educators should move forward to make this emphasis a significant part of every student's science education.

6. Setting Science Education in a Canadian Context

Science education in elementary and secondary schools should take into account the Canadian reality. Every Canadian student should know some of the history of science and technology in Canada and appreciate the importance of Canadian science and technology activity at local, regional and national levels.

In the report of the Commission on Canadian Studies published in 1975, Symons noted that "Canadian school children learn of the accomplishments and impact of science in other countries, such as the Apollo flights and Sputnik, but they learn virtually nothing about the accomplishments and impact of science in their own country. And the reason is that they are not being taught such matters."[4]

This cry of alarm was never really heard. With only a few exceptions, efforts in this direction are made on a local level without great resources and with very limited possibility for wider use. Relating science to the area in which the students live is often an activity for enthusiasts only.

The Science Council believes that the science that is taught to young Canadians should be set in a Canadian context and that this context should include both historical and social aspects. Children in Canadian schools should learn how science and technology have contributed to the shaping of this country. They should learn about the men and women whose achievements and discoveries have been landmarks in Canada's scientific heritage. To encourage this teaching, an information bank about these people should be set up and made available to teachers, to teacher educators and to the writers of school textbooks; access to the bank will also encourage publishers to include this information in their books. The Council also appeals to universities and government agencies whose responsibilities include researching the history of our scientific culture and the preservation of Canada's scientific and technological heritage; these groups too should keep in mind the potential of their work for contributing to the scientific education of young Canadians.

Moreover, the move of science education towards an emphasis on the science-technology-society interaction must be set in the context of Canadian reality. Although scientific knowledge is international in nature, it is supported economically, produced, applied and taught in a specific national context. Canada has many unique features such as its northern latitude and cold climate, the long distances between centres of population, and its abundant natural resources. All of these features make it different from other industrialized countries. On the local level, these characteristics provide many special opportunities to explore the science-technology-society interaction. The communications industry, the salmon cycle in the Atlantic provinces, the hydroelectric industry in Québec, agriculture in Saskatchewan, mining exploration in Ontario and the Northwest Territories, forestry in British Columbia: these are just a few examples. The industrialization of Canada has also created an urban environment that is equally rich in such opportunities.

One way of placing science learning in a Canadian context is by showing that the historical roots of Canadian scientific and technological activity lie in such fields as geology and agriculture but that, during the course of this century, these sciences and technologies have become subordinated, both in status and public interest, to the more theoretical sciences of physics and chemistry. As Wynne-Edwards and Neale explain:

> We came to accept, in the middle years of this century, that science had evolved into separate disciplines in a complex pyramid of

dependent knowledge, with mathematics at the top, physics and chemistry just below and drawing on mathematical fundamentals, then the plethora of life and earth sciences drawing on these three, and on the bottom tier, the applied sciences, such as agriculture, forestry, engineering and medicine, drawing from all above.[5]

They go on to point out that children naturally encounter the sciences from the base of the pyramid first, moving upward only slowly by "successive steps of encounter, discovery, and rationalization."[6] However, education has not used upward steps to natural discovery but has tried to move from the top down in the pyramid of dependent knowledge.

We have defined the apex of the pyramid as the basis of science, and the base of the pyramid as its derived and dependent end... . We have chosen to drive the pyramid of science into the heads of school children point first, with a stiff preliminary dose of "basic" mathematics and sciences taught in isolation. The result is so alienating to most children that only a few persist to become scientists or engineers (in which case they might just rediscover the "real" world around them at last).[7]

Council believes that the time has come to reinstate the "macrosciences" — geology, agriculture, botany, health science, and engineering — as basic to education in elementary and junior secondary school. The more abstract "microsciences" of chemistry, physics, and advanced mathematics can then be built on this firm base. Such a sequence from concrete to abstract would also be consistent with what we know of children's intellectual development and might therefore counteract the present difficulties encountered by younger adolescent students in courses they find "too theoretical." What is proposed is that the term "basic" be seen as basic relative to the physical and intellectual development of the student, not basic to the logical structure of the subject matter. To some degree, this is being done in parts of Canada: agriculture is taught as part of the Prince Edward Island science program; the geology of Newfoundland is a component of elementary science in that province. But much more can be done. The Science Council would like to see teaching materials developed that transform these examples of "Canadian" science into opportunities for all Canadian students to learn about science and about their country at the same time.

Just as the science-technology-society interaction does not necessarily apply to every topic in the science curriculum, so making students aware of Canadian scientific and technological reality does not have to be done exclusively by the use of pan-Canadian examples. In a country with the diversity of Canada, students in any particular region should learn about aspects of the science-technology-society interaction that are peculiar to that region. Furthermore, Council also believes that making this information available to students in other regions will help promote mutual understanding among the students of today who will be the participating citizens of tomorrow.

7. Introducing Technology Education

Technology education should form a greater proportion of secondary school education for all students.

This proposal flows directly from the Science Council's concern that education should be more closely related to the world of work, not as a narrow vocational training, nor simply for nonacademic students, but in an intellectually challenging form designed for all students. We therefore suggest that all ministries of education develop plans for the introduction of technology education as a subject in its own right for students at the secondary school level.

Technology has been defined as "the totality of means employed to provide objects necessary for human sustenance and comfort."[8] Its starting point is human need and its companions are the resources and constraints of human knowledge and natural resources.[9]

Like science, technology can be viewed as a process as well as a product. The goals of a technology component of secondary school education must therefore include both a pedagogy of the "technological product" and the development of technological "process skills." This has been recognized by the Québec ministry of education in its guideline for the compulsory grade 9 course, "Initiation to Technology."

A lesson in technology must be focussed on a technological product (l'objet technique). The study of the technological product involves finding out:

- why was it made?
- how is it made?
- how and why does it work?
- how can one make it?

A technological study thus has two dimensions:

- an intellectual dimension: the design stage involves logic and creativity, as well as mathematical, scientific and technological knowledge;
- a practical dimension: the production stage involves imagination, initiative, manual skills, form and detail recognition, as well as planning and organization.

Thus a lesson in technology involves both knowledge and know-how.[10]

Technology education should promote an understanding of the problem-solving nature and purpose of technology and an awareness of the range of technological activity and potential in Canada today and of its impact on Canadian society. The central focus of units or courses in this area must be on providing students with first-hand experience of the technological methodology for problem solving through the extensive use of project work. For schools to provide these experiences will require new resources, teachers trained in new teaching methods, access to computers and to communications technology, and links to the world of industrial technology.

Courses of this nature will be new to Canadian schools but we can build on the experience of others. In France and the United Kingdom, courses in technology within general education have been in development and testing for several years, mostly at the senior level. Of course, the complexity of the technology and the degree of sophistication of projects will vary according to the level at which technology education is offered. At grade 9 in Québec, for example, the ministry of education suggests five broad themes: technology in your life, technology and construction, technology and mechanics, technology and electricity, and technology and the world of manufacturing. At higher grades in the UK, students are asked to design a method for keeping milk without souring or to formulate spraying recommendations for obtaining maximum crop yield from vegetable seeds.

However, students must become more aware of the use of knowledge to satisfy human needs, and they must also learn the basic skills of technology. Only then will they be more prepared for their participation as creative contributors to the world of work.

8. Ensuring Quality in Science Education

> Assessment techniques must be developed and implemented for *all* the objectives of science education to inform individual students about their progress and to monitor the effectiveness of provincial science education systems.

When achievement of educational goals is not measured, those goals are not valued by students, teachers or the public; this fact has been well documented. In this report, we have referred often to objectives of science education other than learning scientific content and we have emphasized the value of teaching and learning science for the purpose of attaining broader educational goals. These goals, or others like them, have been part of the rhetoric of science education for years. Yet the examinations and tests of science courses, whether set by ministries of education or by teachers, have continued to focus on how much scientific knowledge has been acquired by the student. The effect of this has been that both teachers and students treat other objectives as unimportant extras to be attended to if time allows. And, as every teacher knows, time rarely does allow.

In the United States, standardized achievement tests, notably the Scholastic Aptitude Test (SAT), are used extensively. This has led John Goodlad, a prominent educational researcher, to claim that American educators tend to centre their activities strongly on what he describes as "the small piece of academic shoreline we measure with achievement tests."[11] Public confidence in, and concern for, schooling in the United States rides up and down with the national average of the SAT scores. Goodlad comments further:

> As measures of school performance, standardized test scores fit comfortably with other measures of our assumed well-being, such

as the gross national product (GNP) and the Dow-Jones averages.
A drop in scores calls for a hard-nosed dose of discipline and fundamentals in the schools.[12]

At present, SAT scores in the US appear to be falling, and so public concern is being mobilized to improve education in that country. Goodlad is rightly concerned that a rise in SAT scores will again cause the public to become complacent about science education. Canadians do not have a tradition of standardized achievement testing. If provinces do develop such policies, they should learn from the United States that implementing a program of standardized tests does not, of itself, ensure that schools achieve the goals that are set for them. Tests must be designed to measure all the various goals, even though progress towards some goals is difficult to evaluate.

The Science Council wishes to register its concern that students be assisted towards their educational goals by means of reliable measures of their progress and that the public be given evidence that ministries of education and school systems are indeed monitoring the effectiveness of their science programs. Both of these require reliable instruments and appropriate policies and, in most parts of Canada, the development of both of these is lagging far behind the curriculum developments to which they should be related. There are some promising activities in progress, however. Alberta Education is developing innovative testing instruments for scientific process skills; Ontario has policies in place for a "pool" of items for teachers to use for student assessment (although, regrettably, most of the science items to date are content measures only); Québec has instituted policies for the formative evaluation of student progress, which is designed to provide feedback to the student during the learning process; British Columbia has perhaps the best developed system of provincial assessment designed to provide input to the curriculum development process (science programs have now been assessed twice using this system). These examples are evidence of what can be done. Much more is required and experiences of individual provinces need to be shared.

Of particular importance must be assessment instruments designed to measure progress towards such aims as creativity, problem-solving skills and understanding about science, technology and society. Progress in this assessment area is vital if the worthwhile aims of science education are to be taken seriously.

Conclusion

Many issues have been raised during the study, particularly in discussions at the deliberative conferences. Although this report singles out eight of these issues, the reader should not assume that these are the only directions in which progress needs to be made. In the second chapter of this report, we presented four broad aims towards which the Science Council believes science education should be oriented. We repeat that we regard all of these to be important for every student in school.

While we are optimistic about the directions recommended here, we realize that their implementation will require a high degree of commitment and effort over a long period. Experience has shown that there are no quick solutions and that education is remarkably impervious to change, especially change imposed from outside or above. The strategies for implementing these recommendations (discussed in the following chapter) are therefore as important as the recommendations themselves.

Chapter 6

Strategies for Implementation

The changes recommended in Chapter 5 are the central conclusions of Council's study. But, as we have noted throughout this report, changes in education are often agreed to in principle, even stated in government policy, but fail to become established in practice. The specific recommendations in this chapter therefore focus on ways in which the eight general recommendations may be implemented. Effective change in schools requires the coordinated efforts of many individuals and agencies, hence the need for many specific recommendations. They are grouped in seven clusters as follows:

a.	Curriculum Leadership: Ministries of Education	(1 - 13)
b.	Curriculum Leadership: School Boards	(14 - 15)
c.	Curriculum Leadership: Schools	(16 - 18)
d.	Human Resources	(19 - 30)
e.	Instructional Resources	(31 - 35)
f.	External Resources	(36 - 44)
g.	Research Resources	(45 - 47)

These strategies are based on the assumption that renewal requires more than a change in what has been called the rhetoric of science education.[1] As we have seen in the past, a change in rhetoric does not necessarily produce change in practice. The major thrust of these strategies is therefore towards encouraging and facilitating renewal of science education at the classroom level. Real change is less dramatic, less conspicuous, less politically rewarding than talk about change and it requires patience, understanding and commitment to achieve.

For these reasons, the process of renewing science education must be rooted in the schools, it must be linked with the professional growth of science educators, and it must be supported and nourished by the public and by outside agencies with a concern for science education. This does not mean that ministries of education and their policies are of little significance. Indeed, as the first set of recommendations imply, ministries of education have an important role of curriculum leadership, which must be properly exercised if science teachers are to be clear about what is expected of them.

Curriculum Leadership

In order that changes in science education can take place, a necessary condition is that ministry of education policies explicitly promote the desired changes. The first group of recommendations addresses this condition in relation to the eight general recommendations of Chapter 5.

1. All provincial and territorial ministries or departments of education (hereafter "ministries") should require that science (including computer

studies) be taught for at least 15 per cent (i.e., 45 minutes per day, on average) of the curriculum at the early years of school (to grade 6 or 7).

2. Ministries should outline, in all policy documents relating to science and technology education, concrete steps to be taken by educators to increase the participation of girls in science and technology education.

3. Ministries should ensure that science courses are made challenging and interesting to students of *all* ability levels and learning styles.

4. (a) Ministries should ensure that courses at all levels present a valid representation of the nature of science and scientific activity through the judicious use of examples from the history of science and through careful explanation of apparently everyday terms that are used by scientists in a specialized way (e.g., terms such as "discover," "law," "observe," etc.).

   (b) Elementary science programs should be focussed on the science of the student's environment and include material from such fields as geology, agriculture, forestry, botany, anatomy, engineering, health science and nutrition. Middle-years science programs should gradually add descriptive aspects of physics and chemistry. Advanced theoretical concepts should be postponed until higher-level courses or university. These policies should also influence textbook selection.

5. Ministries should incorporate a science-technology-society emphasis in science courses at all levels. (We suggest an emphasis of 50 per cent in courses at the early-years level, 33 per cent at the middle-years level, and 25 per cent at the senior-years level.) This policy should also influence textbook selection.

6. Ministries should clearly state that Canadian examples of scientific achievement of both men and women and of scientific and technological impact should be used whenever appropriate. This policy should also influence textbook selection.

7. Ministries should develop courses in technology for use at high school level along with policies for their gradual implementation.

8. Ministries should require that students' achievements be evaluated for the full range of science course objectives.

The regular ongoing evaluation of all the objectives of science programs at the school level should be a matter for teachers to plan and administer. For this, teachers should be provided with pretested items from which they can construct tests. In this way, they can ensure consistency of standards and allow for local variation in course content. At the provincial level, such items can also be used for province-wide assessment programs. Given the high degree of commonality in science programs across the country and the considerable resources (especially of time and expertise) required for such test development, the Council suggests strongly that provinces should cooperate in this project.

9. Ministries should cooperate in setting up an interprovincial computerized "item-bank" of tested evaluation items as a resource for both local and provincial examinations.

Apart from the need to assess the progress of each individual student, it is also desirable that each ministry conduct province-wide assessments. The ministry can use this information to show that public investment in education is being monitored, and also to enhance the processes of curriculum review and improvement. In this regard, specially constituted committees can advise ministers on potential changes in the light of province-wide assessments.

10. Ministries should monitor the effectiveness of their science by regular assessments of students' achievements.

11. (a) Ministries should set up provincial advisory councils for science education involving a broad spectrum of interested groups (e.g., educators, policymakers, scientists, industrialists, labour leaders, parents and students).

    (b) These councils should regularly review science curricula and advise ministers on ways to improve policies and practices relating to science education. Councils could, in addition, perform other functions including the promotion of public interest in and support for science education.

One way of stressing the importance of science in education is to require students to take more of it. Currently, only Manitoba requires students to take a science course in grade 11 in order to graduate from high school. In two provinces (Nova Scotia and Prince Edward Island), grade 9 science is the last compulsory course. Council recommends a general increase to the grade 11 standard.

12. Ministries should require all students to take a science course every year to grade 11 as a condition of high school graduation.

The policymaking function of ministries in relation to science education is usually focussed on one individual in each ministry or department with specific responsibilities for science education; this individual may also be responsible for additional subject areas. Rarely does this person have any special training, professional assistance or support, or any opportunity to meet with counterparts in other provinces. Yet science educators expect this official to personify and represent the ministry's leadership in science education in the province. Council feels that adequate recognition and support for these persons is often lacking both inside and outside ministries. In this regard, we have been impressed by the Manitoba system of a "K-12 science working party" or standing committee (made up of teachers and others) who advise and assist the department's science consultant in relation to science curriculum policy.

13. Ministries should ensure that at least one staff member has exclusive responsibilities for science curriculum policy. The designated person should receive training appropriate to the nature of the position, should be adequately supported through professional development, and be enabled to meet regularly with corresponding officials from other provinces. The Council of Ministers of Education, Canada should convene such meetings annually.

Once appropriate provincial policies are in place, the focus of curriculum leadership moves to the school board level, but ministries must also ensure that boards have both the authority and resources to implement science curriculum policies.* The Council has noticed during its study a great variability in boards' capacities to fulfill this mandate. One of the most significant factors, especially in regard to science at the elementary school, is the presence of an individual at the school district level having specific responsibilities in relation to science programs. Such consultants (as they are often called) can provide a unique and valuable service of information and support for teachers and schools in relation to their science programs. For example, the province of Newfoundland has chosen to provide consultants in every school district to assist in the implementation of an elementary science program through providing inservice training for teachers. The impact of these consultants has been significant: 30 per cent more teachers in that province find their inservice education programs to be effective than is the case in the rest of the country. The Council is convinced that an investment in such specialist resources at the district level is essential for improved elementary school programs. In small school districts, it might be possible to have such specialists shared by two boards or for one individual to be responsible for more than one program area (e.g., science and mathematics).

14. School boards should ensure that at least one staff member has specific responsibilities relating to science programs. The designated person should receive training appropriate to the nature of the position, should be adequately supported through professional development, and be enabled to meet regularly with corresponding individuals in other school boards. Ministries should facilitate such meetings on a regular basis.

* Additional recommendations affecting ministries of education include # 18, 22, 23, 29, 30, 32, 33, 34, 35, 38, 41, 44 and 45.

Another direct initiative, which school boards in relatively well-populated areas are encouraged to take, is the establishment of high schools at which science and technology are especially featured. Such "high schools of science and technology" would be the focus of innovation, experiment and excellence for new courses and new teaching methods in science. Students would be provided with a general education of the same type that is offered elsewhere but with expanded opportunities to study science and technology. The schools would be staffed with the most competent and innovative science teachers available, be linked with science, engineering and education departments of local colleges and universities, benefit from close cooperation with industry and welcome girls and boys with above-average interest or aptitude for science. School boards should ensure that these schools contribute to the general improvement of science education in the province (or region) by facilitating the dissemination of local innovations and by promoting models of excellence in teaching science and technology.

High schools with a special orientation already exist in Canada. There are two high schools of music in Montreal, a high school of the arts in Ottawa, as well as one focussed on science at the Ontario Science Centre in Toronto. The Council believes that Canada would greatly benefit from a network of such high schools. However, they must not operate in isolation for the sole purpose of satisfying a group of individuals. The Council recommends maximum interaction between these schools and the others in order to contribute to the general improvement of science education.

15. School boards should set up, where numbers warrant, high schools of science and technology, in which students would receive a regular high school education but where science subjects would be particularly stressed.

The major focus for the renewal of science education should be the school itself and it is at this level that most commitment and effort is required. We are recommending that ministry policies be clear in their expectations and goals and that school boards provide adequate resources for the renewal process*; however, the key individual in the process should be the school principal. The intellectual and social climate of a school and the expectations and demands that these communicate to teachers are shown in our research to be major factors in relation to the orientation of science teaching. According to our case studies, social priorities rather than intellectual ones tend to dominate, even in secondary schools. Science teachers can become preoccupied with fostering diligence, precision, good work habits, attentiveness and the ability to follow instructions; consequently, little emphasis is given to logical argument, critical thinking, selective judgement and creativity. All of these are desirable, of course, but the Council believes that the time is right to reemphasize the intellectual goals of education, particularly in relation to science and technology.

* Additional recommendations affecting school boards include # 18, 21, 23, 24, 29 and 31.

A rebalancing of these priorities cannot come about through ministry edict alone; it must be nurtured through leadership at the school level that recognizes the importance of the intellectual purposes of the school and that takes steps to ensure that these purposes become the primary ones. The need for such leadership, again especially in the elementary school, can also be seen from our research data: nationally, over 60 per cent of elementary school teachers of science stated that there was "no particular leadership and coordination" of science at the school level.

How should such leadership be exercised in relation to science? Our study and discussions with educators have suggested that one major problem confronted by teachers is their isolation, both from each other and the outside world. Once the classroom door is closed, they receive little support or advice and they have little opportunity to observe or consult with their colleagues. Another problem is that policy statements from ministries, together with the attitudes and operations of many board and school administrators, suggest an image of teachers as "mere" implementers of plans for education drawn up elsewhere. Such an image is inconsistent with teachers' preferred view of themselves — as professionals who recognize students' needs and work to meet them. Yet a third problem concerns what Goodlad has called the "career flatness" of teaching — the fact that, for most teachers, the experience acquired from years in the classroom is rarely put to effective use by the schools.[2]

We believe that both the alleviation of these problems and also the grasping of opportunities for renewal of science education call for teachers' involvement in deliberations with each other at the school level. These deliberations should address new directions for science teaching, changes in teaching methods that these imply, and ways in which teachers themselves can acquire the self-monitoring skills required for establishing new science teaching methods.[3] This places the ultimate responsibility for curriculum, instruction and evaluation on the teachers in each school with the "principal teacher" acting as initiator and supporter of the deliberative process, rather than as supervisor or administrator. Principals are not always trained for such a role; indeed, some incumbents may not feel that they can accept it. But if the renewal of science education is to be a reality, this approach appears to be the best, if not the only way of bringing it about. In this respect science is no different from other subjects; if these recommendations were implemented the entire curriculum would benefit.

16. Principals should initiate and actively support deliberations among their teaching staff about the science programs in the school, about the changes needed in teaching methods and in the evaluation of student achievement, and about improved means of teacher development. Once these deliberations have been initiated, their regular organization can be delegated to a department head or other appropriate person.

17. Principals should ensure that it is possible for teachers to observe their colleagues' teaching, to develop the skills of analyzing teaching and to experiment with innovative methods.

For teachers to discuss the dilemmas of teaching (and their private means of coping with these dilemmas in practice) openly and constructively among one another requires also that the climate of the school be as nonthreatening as possible.[4] Teachers, like other professionals, are sensitive to criticisms of their methods and personal styles. If they are expected to adopt new ways of teaching in mid-career, then the school must be a place where pedagogical experimentation — which necessarily implies the possibility of failure as well as success — is not just tolerated but actively encouraged and supported. A critical or threatening climate in which only success is accepted is hardly one in which renewal and change will flourish. School principals must have time and inclination to promote an appropriate climate.

18. Ministries and school boards should support principals in initiating deliberative processes among teachers concerning ways to improve science education. This support should include, where necessary, the provision of administrative assistance to free principals' time for curriculum leadership responsibilities.

Human Resources

The strategies advocated here link the processes of curriculum implementation to those of teacher growth and development. Indeed, the function of inservice education for science teachers is inseparable from the process of science curriculum change. Since few new teachers are entering the school system, inservice education or retraining of teachers is now at least as important as preservice education in promoting the renewal of science education. Yet our research has shown that at present, for two-thirds of all science teachers, inservice education programs are either nonexistent or ineffective. One reason for this is the frequent lack of focus or long term purpose of these programs. If the renewal of science education is to be based in the school, then the school should also become the focus for planning and coordination of teachers' personal growth and continuing education. That does not mean, of course, that the resources of a school are all that are required for inservice education. But the focus of planning and control should be at the school and very much a part of the deliberations among the teachers.

Science teachers, as professionals, should be responsible for their own growth and development. At the same time, unlike some professionals in other fields, they are employed by publicly funded institutions. Accordingly, this development should be oriented towards the goals of the science program and the needs of the school. Furthermore, the professional development and continuing education of teachers needs to be planned on a long-term basis. Inservice education needs to be individualized, long term and school-focussed. At present most of the inservice programs designed for the professional development of science teachers are group-oriented, short term, and removed both physically and conceptually from the problems of the classroom. Accordingly, the Council proposes that among the agenda items for in-school deliberations should be the professional development needs of the teachers.

19. Science teachers should develop annually, in consultation with the school principal, a three-year professional development plan setting out personal goals and developmental needs (in relation to the school science program) and strategies for meeting these goals.

Time for professional development is handled very differently from district to district across Canada and sometimes proves to be a contentious issue. We believe that, in principle, time for professional development should be provided by school boards and teachers. In our judgement, a fair balance is represented by the following recommendation.

20. Science teachers should use a minimum of 15 days annually for professional development activities, five of which may be during the regular school year (i.e., at the school board's expense).

As we have noted earlier, there are examples throughout the country of quality science teaching as recommended in this report. There are exemplary elementary school science programs, there are teachers who have particular ways of teaching about technology in the Canadian context, there are inservice education programs that are school-focussed and long-term. School boards and principals should, we believe, make a greater effort to recognize these innovators and use their experience for the benefit of others. Such experiences can often form the basis of useful inservice opportunities for other teachers.

21. School boards and principals should encourage innovation and excellence in science teaching by providing opportunities for those with particular knowledge or experience to share it with other schools and other teachers.

Even with improved sharing of expertise among schools and teachers, there must be adequate numbers of well-trained teachers for science teaching. There are three distinct issues here: numbers — are there sufficient science teachers?; certification requirements — are the formal qualifications required for science teaching adequate?; science teacher education programs — do science teachers actually receive what they need by way of preparation and training? In recent months considerable anxiety has arisen in the United States about the first of these. In Canada, a survey of school boards did not reveal any such shortage. On the other hand, although most teachers possess the formal qualifications required (by their ministries of education) for teaching science, not all of them are equally equipped to do so. At the senior secondary level, for example, over 95 per cent of science teachers have degrees containing at least some science; 16 per cent, indeed, are at the postgraduate level. By contrast, at the junior high level, over one-third of those teaching science have had no university science courses, and in the early years, three-quarters have had no formal education in science since they were in high school.

What is disturbing about these facts is that, in the eyes of most ministries of education, all of these groups are equally "qualified" to teach science. Teachers' certificates in most provinces are of a general nature; that is, they do not specify those subjects that the holder is qualified to teach nor the level at which a subject may be taught. The Council regards this practice as unfair to the teachers and the students. Students at all levels are entitled to be taught science by someone with at least some university-level training in the subject and teachers without such a background who are assigned to teach science should be provided with appropriate upgrading by their employer.

22. (a) Ministries should indicate on teaching certificates those subjects that teachers are regarded as qualified to teach as a result of their having completed a minimum number of university courses in the relevant subjects.

    (b) Ministries of education should consult with science teachers, deans of science and deans of education in determining the precise requirements in each province.

The designation of subjects that teachers are qualified to teach would be of little significance if these qualifications are ignored when teachers are appointed or laid off. These matters are subject to collective agreements between educational authorities and teachers' unions.

23. Ministries, school boards, and teachers' unions should recognize the vital importance of maintaining well-prepared teachers in the classroom by taking teachers' qualifications as well as seniority into account when negotiating collective agreements.

Even if the system of "bumping" teachers is adjusted as recommended here, some unprepared teachers will inevitably be assigned science classes. Under these circumstances, the Council considers that school boards, as employers, should accept responsibility for providing appropriate training to the teacher.

24. Where teachers assigned to teach specific subjects lack the appropriate background, school boards should require teachers to take additional training in those subjects and should provide time for such additional training.

Although the Council did not extend this study to university science education, that is where science teachers, at least secondary school teachers, are taught their science. There they are either taught or not taught about technology, about the history and philosophy of science, about the Canadian context of science, and there they develop attitudes about the relevance of these and other important matters. What future teachers learn is not a concern for faculties of education alone, even though they traditionally interpret certification requirements and the overall university requirements for teachers in any given province. Indeed, education faculties encounter students for professional training who have already formed their knowledge and attitudes on these matters. In science courses, university students form attitudes (often on the basis of offhand and implicit communication) about engineering, about the history of science, about the significance of Canadian contributions to science and technology, about ethical and other societal concerns associated with scientific endeavour, and even about the importance of science teaching in schools. Faculties of humanities and engineering also have a role to play if the university requires that science teachers study, for instance, the history and philosophy of science and the nature of engineering as a foundation for technological development. At least four university faculties ought to have a significant role in the development of well-informed science teachers, and indeed the entire university has an obvious stake in the outcome.

25. Presidents of all universities preparing elementary and/or secondary school science teachers should ensure that deans of education, science, engineering and humanities cooperate to make provision (both in policies and in course offerings) for adequate science teacher education programs. Special attention should be given to developing teachers' understanding of the philosophical, social and historical context of both science and technology, as well as to the strength and breadth of their background in scientific subject matter.

Attracting top quality students to professional training in science education is too important to be left to chance. Although academic entry requirements to faculties of education can provide a check on the academic standard of science teachers, other measures can assist.

26. University and other postsecondary faculties of science and engineering should make special efforts to encourage highly qualified students to pursue careers in science education as well as in science and engineering.

If science teachers are to teach about such matters as science in a social context or the role of science in technological development, then they will need to be taught how to do so. Similarly, if the men and women who teach are to encourage both girls and boys in science, then teachers need to learn about the ways in which social attitudes can condition girls and boys to develop different expectations of themselves, different feelings of competence and different degrees of interest in science and technology.

27. University programs should prepare science teachers to use an array of alternative teaching methods and programs in order to have students reach correspondingly different objectives in science education. In particular, teaching methods about the interactions of science, technology and Canadian society should be stressed.

28. University programs should prepare science teachers and counsellors to understand the particular society-induced difficulties faced by girls in relation to science education, and to develop methods of compensating for these difficulties.

Even though preservice science teacher education programs ought to involve many aspects of science education, only a few are feasible. Many aspects of science teaching cannot be taught to teachers-in-training before they have acquired the basic competencies of teaching. One of the major functions of preservice teacher education is to enable the novice to "survive" the first year of teaching.[5] Under such circumstances, students at this stage of their professional growth cannot be expected to master alternative styles of teaching appropriate to different types of educational objectives nor to acquire the skills of self-monitoring essential for teacher growth.

Yet, despite this constraint on what is feasible in preservice training, teachers — perhaps uniquely among professionals — are regarded as fully qualified immediately on completion of their formal university training. Any expectations they have for further training are largely a matter of personal motivation, and frequently they experience a discontinuity between preservice and inservice teacher education and between undergraduate and graduate study in education. Teacher education must be organized to provide a learning process that continues on into the inservice years, and teachers must be motivated to participate in this career-long learning. Otherwise, science teachers may never develop beyond the stage at which they first entered the classroom. And if their major orientation then was towards teaching science content for its own sake, that orientation can remain unchallenged indefinitely. New approaches to training science teachers are therefore needed: to stress continuous learning over a period of several years (following entry into the profession); to link the undergraduate (BSc/BEd) programs with graduate (MSc/MEd) programs; and to develop higher level professional skills (such as those associated with curriculum development and with the analysis of science teaching).

29. University faculties of education, in consultation with other faculties within the university, ministries, school boards and the teaching profession, should develop and test new models of continuous teacher education with both preservice and inservice components.

These long-term changes to the system of preservice education of science teachers will not, however, alleviate the immediate problems of teachers who are currently in the schools but whose own training is now seen to be inadequate. Elementary school teachers, in particular, require retraining urgently if they are to be able to teach science properly. They require not only content knowledge of science, but also knowledge about science and science teaching methods. A special effort is required so that, by 1990, every teacher of science in Canada will have taken at least one university course in science or science teaching. We estimate that at least 50 000 teachers now teaching in schools are in need of such a course. Accordingly we propose a series of summer institutes to be conducted by university faculties of education in every province; the program will draw on existing expertise among science teachers in elementary schools. We stress that such a program is not a permanent solution, but a short-term (five to ten years) strategy to ensure that the present generation of Canadian students can receive immediate benefit.

30. Ministries of education, in conjunction with faculties of education, should establish special summer institutes in science education for the purpose of upgrading science teachers lacking appropriate preparation, and take all necessary steps to ensure that teachers needing to attend them are able to do so.

Instructional Resources

Teaching science well also requires adequate facilities and equipment. This usually means that students should be guaranteed access to a laboratory or science room equipped with running water, natural gas and a number of electrical outlets. Most high schools actually have these facilities. At the elementary level, however, fewer than one teacher in five has even occasional access to a room equipped for science activities. Moreover, elementary school teachers often lack appropriate curriculum resources (hardware, consumables, kits, etc.) for science courses. In order to provide elementary science teachers with such resources, the Calgary Public School Board operates a resource centre where a large number of equipment kits are collected, maintained and stored under the supervision of a full-time technician. Teachers pick up the kits they need, bring them to the school, use them and share them with colleagues before returning them to the centre. There, consumables are replaced and the kits, after maintenance, are again available to teachers. The Science Council believes it to be an interesting and innovative solution to the problem of the lack of science resources in the elementary school.

31. (a) School boards should ensure that all classrooms in elementary schools are appropriately and safely equipped in order to allow science activities to take place.

(b) Wherever the material to carry out scientific experiments or demonstrations is lacking, school boards should establish a science resource centre where such material is made available for elementary science teachers.

Teaching science requires more than well-trained teachers and adequate facilities, however. Our research has shown that, not only do 90 per cent of students at senior levels of high school use a science textbook, 80 per cent of their teachers use textbooks as the main resource for lesson preparation. And, as our analysis of textbooks now in use has shown, the orientation towards science, technology and Canadian society is only present in a few of them and rarely in a balanced form. In days past, it might have been regarded as reasonable under the circumstances to settle for less than satisfactory books (usually obtained from the United States). The reasons for no longer doing so are overwhelming. When the goals of science education merely involved the learning of science content or acquiring scientific skills, it could be argued that these goals are supranational and therefore texts from any source should be adequate. Now that the goals of science education concern science, technology and society, Canadian books must be developed that deal with the impact of science and technology on Canadian society.

Our analysis has also shown that the student activities prescribed in laboratory manuals develop only the lowest-level scientific skills. Yet guidelines from nearly every province call for the development of critical thinking, creativity and a realization of the limits of scientific inquiry. Textbooks must take such objectives seriously and provide teachers with improved teaching strategies and evaluation suggestions for laboratory activities.

Despite the need for such books, economic factors will discourage their development in the foreseeable future unless new structures are established for this purpose. Commercial publishers are constrained by the limited overall size and fragmentation of the Canadian market and by the need to obtain separate approvals for each province. They therefore concentrate on textbooks with a traditional orientation — what teachers are used to — and on the science topics prescribed by ministry policies. Authors and publishers have little incentive to be innovative. The problem is not new in Canada; the operation of a completely free market is not always in the best interests either of the country as a whole or of the provinces (only Ontario and Québec have large enough populations for real competition among textbooks specially written for their programs).

Ministries should provide special guidelines for textbook authors and publishers. These guidelines should specify precisely all the objectives that the textbooks should take into account and related criteria for the evaluation of the textbooks. The example of the Québec ministry's "Direction du matériel didactique" (curriculum resources division) is particularly noteworthy in this respect. While this policy model may not be universally applicable, other provinces are encouraged to consider it. Our recommendations therefore concentrate on the need to bring commercially published material more into line with all the objectives prescribed by ministries and also to support the development of innovative textbooks with an orientation towards science, technology and society.

32. Ministries and publishers should develop a system for review and approval of textbook manuscripts that enables changes to be made before production.

33. Ministries and publishers should study the feasibility of preparing textbooks for multi-provincial use in which material for individual provinces is included in provincial supplements or versions.

Commercially published textbooks are not the only curriculum resource for teachers. Many excellent programs are based on locally developed and informally distributed materials. Compared with textbooks, such materials are relatively easily updated; they thus have a complementary role to play with the more formal and permanent textbook. What is required is that such materials be evaluated, that those of high quality be made more generally available, and that further development work at the local level be stimulated. To meet these goals, a new structure is needed.

34. A Canadian Foundation for Science and Technology Education should be established (based on the existing Society, Environment and Energy Development Studies (SEEDS) Foundation) to be funded by industry and by federal and provincial governments to:
    a. initiate development work;
    b. provide for testing, evaluation and quality control;
    c. disseminate material in both languages across Canada;
    d. act as a clearinghouse for existing materials;
    e. develop plans for the use of computer and video technology for a curriculum resource system for Canadian schools, particularly those in remote locations.

The proposed foundation should not be interpreted as a threat to provincial autonomy. Ministries still have the responsibility to lead by selecting objectives and by authorizing textbooks for use. However, if textbooks do not exist to enable students to attain educational objectives, then the autonomy is hollow. The foundation proposed here would also function as a publisher — though in a non-profit manner — in stimulating the development of curriculum materials not otherwise available. This, we believe, represents an enhancement of real provincial autonomy. Nor should the aims of the proposed foundation be confused with those of the research centre proposed in recommendation #45. The purpose of the university-based centre would be to study new approaches to science teaching whereas that of the independent foundation would be to produce materials for school use. Each of these should complement the other.

The presence of computers in an increasing number of Canadian schools offers unparalleled opportunities for the improvement of education (including education in science) if opportunities to use them intelligently are grasped and exploited fully. It would be disastrous if they were used merely to automate the mistakes or inadequacies of the past. We see their potential in terms of making possible, in a new way, the achievement of aims set out in this report. First, "Science for All" can become a reality if computers are used to enable each student to learn science in an individualized way. This will require research into how children learn complex concepts and into how teachers can best use computers to this end. Second, the emphasis on science in a technological and societal context and on technological problem solving requires that new teaching approaches (such as simulations) be available to teachers. Computers can facilitate the use of such methods if appropriate software is developed. Both of these goals urgently require nationwide cooperation in research and development. The alternative is the extensive importing of educational software, a process that not only has negative economic consequences but also effectively exports our educational decision making.

35. (a) Federal and provincial governments should collaborate in setting up centres for research and development in computer-aided learning.

    (b) Ministries should ensure that software to be used in school science courses is coordinated with all the aims of science education.

External Resources

For teachers to be able to relate science to technology and to social issues, they must themselves receive up-to-date and helpful support and assistance. Many organizations and groups of individuals in Canada can support science education in this way and some are already doing so. We have already discussed the role of the universities; other groups include the scientific community acting both as individuals and through their professional organizations; labour and industry, especially those companies having a particular orientation towards science and technology; public institutions concerned with science and technology including government departments, museums and science centres; and the general public and local communities.

The scientific and engineering professions in North America have often been much further removed from the activities of school science education than have their counterparts in Europe. Here university scientists and professional engineers are rarely active members of associations of science educators. Yet their stake in school science is obvious. The Council believes that the science and engineering communities should be more supportive of those who teach science in school and offers two practical suggestions for demonstrating such support.

36. The Royal Society of Canada in cooperation with the Canadian Association for Science Education should provide annual awards for excellence in science education.

37. The Royal Society of Canada, L'Association canadienne-française pour l'avancement des sciences (ACFAS), the Association for the Advancement of Science in Canada (AASC), and other associations of scientists and engineers should identify (to ministries of education and to science teachers' associations) those of their members who are willing to contribute time and advice to science curriculum development and inservice education.

Science-based industry also has a major interest in the quality of science education in schools, as was demonstrated by the participation of representatives of business and labour at the provincial deliberative conferences. It is a sad fact that many teachers of science have little or no first-hand experience of industrial applications of the science they teach. There are many ways to rectify this lack of experience. Science teachers could spend time (e.g., during the summer or while on study leave) in an industrial setting. A comparable experience might be provided by a university or government research centre in science or engineering. Under certain circumstances, teachers might be given credit for such experience towards a graduate degree in education (in a system similar to the University of Waterloo co-op undergraduate programs). Scientists and engineers from industry could be invited to visit schools to give demonstrations or lectures. As the experience of the SEEDS foundation has shown, industry can contribute significantly to the development of curriculum resources (see recommendation #34) and to the sponsorship of special fellowships for science teachers (e.g., the Shell merit fellowship program at the University of Calgary) or of awards for excellence in science education (e.g., recommendation #36). Many projects are taking place in Canada in which schools and local industries are working together for the improvement of education. But more can be done.

38. Science teachers' associations, industrial organizations and ministries of education in each province should establish task forces to recommend ways in which science educators and industrialists can cooperate for the improvement of science education.

There are many avenues of support for science education that are sometimes overlooked by teachers. Some of these, such as the media (both electronic and print), museums and science centres have a partly educational function themselves, while others such as government departments and other public institutions often possess scientific or technological information of potential value to schools. All of these can help both teachers and students learn more about science and technology in a Canadian context. Better liaison is required, we believe, between the producers of information and the consumers of it in schools.

39. Teachers should ensure that science columns from newspapers and magazines as well as magazines devoted specifically to Canadian science and technology (such as *Science Dimension*) are available in schools and that they are used in class whenever appropriate.

40. (a) Ministries should ensure that museums and science centres are aware of science curricula and that these institutions promote resources having particular importance to those curricula.

(b) Teachers should ensure that they are aware of the potential uses of such out-of-school resources as museums and science centres, and that these are used to enhance their science programs in school.

41. Science teachers' associations should investigate sources of scientific information at all levels of government and make the results of such investigation available to their members.

With the need to promote greater participation of girls in science and technology, the schools must play their part as we noted in Chapter 5. But they cannot be expected single-handedly to alter traditional attitudes about girls and science. There is a strong case here for a national information program on this subject.

42. The Minister of State for Science and Technology and the Minister responsible for the Status of Women should together sponsor a large-scale public information program directed especially towards parents and designed to raise public awareness of the need for girls and young women to participate in science and technology education.

There are, finally, many resources for science teaching to be found in local communities, among parents and members of the public. All that can be done to bring science and technology into the school from the outside world should be done. Teachers and school principals should ensure that their relations with parents' groups are such that no opportunities are missed for drawing on this type of experience. Two volunteer-based organizations dedicated to bridging the gap between schools and their communities are the Youth Science Foundation and the Conseil de développement du loisir scientifique. They organize science fairs, publish periodicals (*Youth Science News* and *Science-Loisir*), and promote community interest and involvement in science. Plans for development and expansion are in place: all that is required is additional funding. Principal sources of funds are the federal government with provincial governments and industry also providing support.

43. Funding for the Youth Science Foundation and the Conseil de développement du loisir scientifique should be increased and guaranteed for a five-year period.

The degree of public support for science education is, of course, related to the degree of public awareness. Ministries of education, science teachers' organizations, and others involved in science education must take steps to make the public more aware of what is being done in science education and what ought to be done. On a local level, such activities as a science open house, a science fair, or a technology fair are useful means of doing this. On a broader level, the occasional national conference focussing on the importance of science education would raise the profile of this important activity.

44. All levels of government should cooperate with scientific and teachers' organizations in periodic national conferences on science education.

Research Resources

Further research is required in many of the areas identified in Chapter 5 as initiatives for immediate action. For example, the development of science education teaching methods oriented towards the science-technology-society interaction requires more conceptual work and empirical testing. The experiences of girls who study science in Canadian schools have scarcely been examined. Even data concerning their enrolment in science subjects are not always available. And the development of new forms of evaluation for science education corresponding to the more complex objectives is still in its infancy.

Canada has adequate numbers of excellent science education researchers, as the special interest group in science education of the Canadian Society for the Study of Education demonstrates. Furthermore, the work of many of these researchers is known internationally; in the area of science-technology-society education, for instance, Canada has taken an international leadership role. But one of the worst problems for science education researchers in Canada is the extent of their separation. Because of the provincial basis of education, science education researchers are thinly spread across Canada rather than concentrated in centres where a "critical mass" might result in a larger volume of significant work. The Council therefore proposes the setting up of a research centre with a program focussed on science-technology-society education to function as a network of university researchers from all parts of Canada who are doing work in this field.

45. An interprovincial research centre should be established and supported by both federal and provincial governments. The mandate of the centre would be to investigate new approaches to teaching science, especially in relation to technology and Canadian society.

A new and useful research project in Canadian science education would be one that has already been implemented in the United States. In that country, a nationwide "search for excellence in science education" has been instituted by the National Science Teachers' Association and 50 cases of excellent science teaching in schools were identified in 1982. If such a program were mounted in Canada, researchers could contribute to our collective understanding of excellence in science education by conducting case studies of these exemplars.

46. The Canadian Association for Science Education (CASE) together with the science education special interest group of the Canadian Society for the Study of Education (CSSE) should develop a program to identify and describe examples of excellence in Canadian science education.

In addition, many of the recommendations in this report urgently require research and development funds over the next several years. The Social Sciences and Humanities Research Council of Canada (SSHRCC) is responsible for research support in the field of education and the area of science education is closely related to one of its present areas for strategic funding: the human context of science and technology.

47. SSHRCC should set up a sub-program of strategic grants for research in science education related to implementation of recommendations from this report.

Conclusion

If these recommendations are implemented, an unprecedented stimulation of science education will take place in Canada that will directly benefit every Canadian child now in school as well as the next generation. Such a benefit requires an initial investment and the Council has considered the costs of implementing its recommendations. Over half of the recommendations (26 out of 47) can be implemented at no additional cost to the taxpayer. This is the case, for example, in ensuring that textbook authors include Canadian examples, that teachers use classroom practices that encourage girls to study further science, and that science teacher education programs include information about the history of science. We estimate the costs of implementing the remaining recommendations at $155 million spread over five years (see Appendix for detailed estimates). Expressed in other terms, this is 0.154 per cent of present expenditures for elementary and secondary education in Canada or about $6.28 per student per year. The Council regards such an investment as modest given the expected benefits and as consistent with the climate of restraint now evident throughout the country.

The major theme of these recommendations has been the need for leadership on the part of ministries of education, school boards, and the teaching profession. They cannot, however, be expected to provide this leadership in a political vacuum. When parents and other members of the public unite in support of education change, then plans can become realities. The Council has described in this report goals for science education that are feasible and urgently needed. We now call upon the Canadian people to ensure that the renewal of science education — both at the provincial and the local level — becomes a reality. Our children deserve it.

Appendix

Cost Estimates for Implementing Recommendations

Recommendation	Cost $ thousands	5 Yr. Cost $ thousands
9. Test-item bank	4 000	4 000
10. Provincial assessments	3 000	3 000
11. Provincial advisory councils	50/yr.	250
13. Science consultants (ministries)	30/yr.	150
14. Science consultants (boards) 300 full-time equivalents	12 000/yr.	60 000
15. High schools of science and technology: 10 schools, 500 students each, start-up costs	10 000	10 000
21. Outstanding teachers: 125 full-time equivalents	5 000/yr.	25 000
29. Research on new models of teacher education	300/yr.	1 500
30. Summer institutes	2 000/yr.	10 000
31. Facilities & equipment, elementary schools	10 000	10 000
34. Canadian Foundation for S&T education (trust fund)	15 000	15 000
35. Research centres (computer-aided learning)	2 000	10 000
36. Royal Society/CASE: 5 awards per year, $2 500 each	12.5/yr.	62.5
37. Part-time staff person	10/yr.	50

Recommendation	Cost $ thousands	5 Yr. Cost $ thousands
38. Industry/school task forces	50	50
42. Public information program	200	200
43. YSF and CDLS	150/yr.	750
44. National conference	250	250
45. Research centre	600/yr.	3 000
46. Project "excellence"	200/yr.	1 000
47. SSHRCC strategic grants	200/yr.	1 000

Total cost (5 yr.) Average cost per year	$155 262 500 $ 31 052 500
Total expenditure on education (elementary and secondary levels) 1983-84:	$20 110 589 000
Total elementary-secondary enrolment, 1983-84:	4 946 690 students
Total cost of implementing recommendations, as a percentage of the total cost of education:	0.154%
Total cost per student per year:	$6.28

Notes

I. Science Education for Tomorrow's World

1. Hereafter, the word "provinces" will be used to refer collectively to both provinces and territories.

2. In this study, the word "ministry" is used as the generic term for the branch of the provincial or territorial government responsible for education.

II. Why Study Science?

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4. Donald A. George, *An Engineer's View of Science Education*, Discussion paper, Science Council of Canada, Ottawa, 1981, p. 29.

5. See John Ziman, *Teaching and Learning About Science and Society*, Cambridge University Press, Cambridge, 1980.

6. Aikenhead, *op. cit.*

7. Page, *op. cit.*

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11. George, *op. cit.*

12. E.R. Ward Neale, "Re-integration of Science and the Humanities," Address to the Science Council of Canada deliberative conference on science education in Newfoundland, Gander, 9 May 1983.

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III. The Context of Science Education

1. This and subsequent data are drawn from: Graham W.F. Orpwood and Jean-Pascal Souque *et al.*, *Science Education in Canadian Schools*, Background Study 52 (3 volumes), Science Council of Canada, Ottawa, 1984.

2. Pierre-Léon Trempe, "Lavoisier: Science Teaching at an École Polyvalente," in *Science Education in Canadian Schools*, volume III (Case Studies of Science Teaching) edited by John Olson and Thomas Russell, Background Study 52, Science Council of Canada, Ottawa, 1984, p. 233.

IV. Present Directions in Science Education

1. This point is amplified in Janet Ferguson (ed.), *Who Turns the Wheel?*, Proceedings of a workshop on the science education of women, Science Council of Canada, Ottawa, 1982.

2. Graham W.F. Orpwood and Jean-Pascal Souque, *Science Education in Canadian Schools*, volume I (Introduction and Curriculum Analyses), Background Study 52, Science Council of Canada, Ottawa, 1984.

3. A notable exception is Bernie Galbraith, *Science Process Skills and the Alberta Science Curriculum*, Position paper, Alberta Education, Edmonton, 1983.

V. Conclusions and Recommendations

1. Conseil supérieur de l'Éducation du Québec, *Le sort des matières dites "secondaires" au primaire* (The fate of "secondary" subjects at elementary school), Report to the Minister of Education, Québec, 1982.

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12. *Ibid.*

VI. Strategies for Implementation

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Statements of Council

Supporting Canadian Science: Time for Action, May 1978
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Toward a Conserver Society: A Statement of Concern, by the Committee on the Implications of a Conserver Society, 1976, 22 p.

Erosion of the Research Manpower Base in Canada: A Statement of Concern, by the Task Force on Research in Canada, 1976, 7 p.

Uncertain Prospects: Canadian Manufacturing Industry 1971-1977, by the Industrial Policies Committee, 1977, 55 p.

Communications and Computers: Information and Canadian Society, by an Ad Hoc Committee, 1978, 40 p.

A Scenario for the Implementation of Interactive Computer-Communications Systems in the Home, by the Committee on Computers and Communication, 1979, 40 p.

Multinationals and Industrial Strategy: The Role of World Product Mandates, by the Working Group on Industrial Policies, 1980, 77 p.

Hard Times, Hard Choices: A Statement, by the Industrial Policies Committee, 1981, 99 p.

The Science Education of Women in Canada: A Statement of Concern, by the Science and Education Committee, 1982, 6 p.

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Research and Development in Canada, a report of the Ad Hoc Advisory Committee to the Minister of State for Science and Technology, 1979, 32 p.

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No. 6. **Background Studies in Science Policy: Projections of R & D Manpower and Expenditure**, by R.W. Jackson, D.W. Henderson and B. Leung, 1969 (SS21-1/6, $1.25), 85 p.

No. 7. **The Role of the Federal Government in Support of Research in Canadian Universities**, by John B. Macdonald, L.P. Dugal, J.S. Dupré, J.B. Marshall, J.G. Parr, E. Sirluck, and E. Vogt, 1969 (SS21-1/7, $3.75), 361 p.

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No. 11. **Background to Invention**, by Andrew H. Wilson, 1970 (SS21-1/11, $1.50), 77 p.

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No. 52. **Science Education in Canadian Schools. Volume I: Introduction and Curriculum Analyses**, by Graham W.F. Orpwood and Jean-Pascal Souque, April 1984 (SS21-1/52-1-1984E, Canada: $8.00, other countries: $9.60). Volume II: Statistical Database for Canadian Science Education, by Graham W.F. Orpwood and Isme Alam, April 1984 (SS21-1/52-2-1984E, Canada: $5.50, other countries: $6.60). Volume III: Case Studies of Science Teaching, by John Olson and Thomas Russell, April 1984 (SS21-1/52-3-1984E, Canada: $10.95, other countries: $13.15).

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Science and the North: An Essay on Aspirations, by Peter Larkin, 8 p.

A Nuclear Dialogue: Proceedings of a Workshop on Issues in Nuclear Power for Canada, 75 p.

1977

An Overview of the Canadian Mercury Problem, by Clarence T. Charlebois, 20 p.
An Overview of the Vinyl Chloride Hazard in Canada, by J. Basuk, 16 p.
Materials Recycling: History, Status, Potential, by F.T. Gerson Limited, 98 p.

University Research Manpower: Concerns and Remedies, Proceedings of a Workshop on the Optimization of Age Distribution in University Research, 19 p.
The Workshop on Optimization of Age Distribution in University Research:
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Proceedings of the Seminar on Natural Gas from the Arctic by Marine Mode: A Preliminary Assessment, 254 p.
Seminar on a National Transportation System for Optimum Service: Proceedings, 73 p.

1978

A Northern Resource Centre: A First Step Toward a University of the North, by the Committee on Northern Development, 13 p.
An Overview of the Canadian Asbestos Problem, by Clarence T. Charlebois, 20 p.
An Overview of the Oxides of Nitrogren Problem in Canada, by J. Basuk, 48 p.
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Appropriate Scale for Canadian Industry: A Proceedings, 211 p.
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Opportunities in Canadian Transportation:
- Conference Proceedings: 1, 162 p.
- Auto Sub-Conference Proceedings: 2, 136 p.
- Bus/Rail Sub-Conference Proceedings: 3, 122 p.
- Air Sub-Conference Proceedings: 4, 131 p.

The Politics of an Industrial Strategy: A Proceedings, 115 p.

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What is Scientific Thinking? by A. Hugh Munby, 43 p.
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Québec Science Education - Which Directions?: A Proceedings, 135 p.
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Science Council of Canada

Conseil des sciences du Canada

Summary of Report 36

Science for Every Student

Educating Canadians for Tomorrow's World

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Canadian Science Education: Initiatives for Renewal

1. Elementary schools must provide science education for all their students
2. Girls must be encouraged to continue with science throughout their schooling
3. High achievers and science enthusiasts must receive greater challenge
4. Science education must provide a more accurate view of the practice, uses and limitations of science
5. Science education must include study of how science, technology and society interact
6. Students must be taught how Canadians have contributed to science and how science has affected Canadian society
7. Technology courses must be included in the secondary school curriculum
8. Teachers and curriculum planners must evaluate students' progress towards *all* the goals of science education, not just their learning of scientific content

Canada's future citizens and decision-makers are in school today. When they leave, they will face a world made daily more complex by rapid scientific and technological developments. To cope with such a world, Canadians must be literate not only in the traditional basics of language and mathematics, but also in the new basics of contemporary society: science and technology.

How well is Canada's educational system equipped to meet the need for scientific literacy for all? Do students receive enough science education? Is it appropriate to individual needs? Are some groups - girls, for instance - neglected? What science should students be taught and how should it be taught to them? What indeed are the aims of science education?

To answer questions of this kind, the Science Council of Canada embarked on a four-year study of science education in Canada's elementary and secondary schools. The study, which involved an extensive research program and consultation with many groups inside and outside the educational system, reached this conclusion: renewal in science education is essential. Now.

In Report 36, *Science for Every Student: Educating Canadians for Tomorrow's World*, the Science Council analyzes the study's findings and presents recommendations for bringing about this renewal. The report is organized in four sections:

- Why Study Science?
- Science Education Now
- Opportunities for Renewal
- Strategies for Implementation

Why Study Science?

A significant part of the Science Council's study consisted of consultation with all the groups that have an interest in science education: educators, ministry and school board officials, parents, students and others. This process revealed an emerging consensus on the purposes of science education. Science education, it was generally agreed, can benefit all students. But the fullest benefits will only be realized from a science education appropriate to individual needs and designed to enable students to:

- participate fully in a technological society as informed citizens;
- pursue further studies in science and technology;
- enter the world of work;
- develop intellectually and morally.

Science for the Informed Citizen

In an age of technology, this aim of science education must be among the most important. If members of society fail to understand the interaction of science, technology and society, they lose control of the most potent forces shaping their world.

International momentum towards a science education that incorporates such a science-technology-society (STS) emphasis is growing. The Canadian contribution in this direction is already significant, and it seems likely that the STS dimension will become firmly established in Canadian science education.

Science for Further Education

Historically, one of the major functions of schooling has been to prepare students to enter university or college. Now, educators are beginning to broaden the meaning of postsecondary study to encompass lifelong learning, and consequently to ask what kind of preparation is appropriate for this.

Ideally, science education is a preparation and encouragement for students to learn about science throughout their lives. Science studies should be linked not only to previous and subsequent science learning but also to other areas of study. Moreover, students should not be passive recipients of scientific information but actively critical of science itself. A science program based on these goals can prepare students for a lifetime of learning and enable them to examine their own knowledge critically.

Science for the World of Work

Society needs trained workers and individuals need employment. Because technology will be a factor in the careers of many students, they must learn how technology will influence the nature of work, the workplace and career opportunities in the future.

Science education must not be restricted to a presentation of information but should offer the student real problems that can be solved by processing information in a creative way. In the future, many jobs will involve the ability to use available information, not just the ability to acquire and retain it.

Science for Personal Development

Science education can contribute to the development of rationality and the ability to think critically. As a discipline that uses rational argument and critical thinking (along with the arts and humanities), science can be the means by which students develop skills such as observing, classifying and hypothesizing. Moreover, because the concepts of science can be used to explain so much, science education can help students understand and control their world. For science education to promote intellectual growth, its teaching must start where the child is in terms of skills and knowledge.

Science Education Now

Science for Every Student bases its conclusions on an extensive database on science education in Canada, compiled over the course of four years of research by the Science Council.

The research was designed to examine the science curriculum at three levels:

- the intended curriculum, that prescribed by ministries of education, was analyzed by an examination of curriculum guidelines published by each province or territory;
- the planned curriculum, that developed by school boards and individual teachers, was the subject of a survey of Canadian science teachers and a review of the prefaces of science textbooks;
- the taught curriculum, that experienced by the students in the classroom, was investigated by an analysis of the content of 33 commonly used science textbooks and eight case studies of science teaching in various parts of Canada.

(A fourth level, the learned curriculum, would have required an evaluation of students' achievements in science. Because student evaluation was regarded by provincial ministries of education as their own prerogative, the Science Council agreed not to analyze the science curriculum at this level.)

The Intended Curriculum

The four aims of science education described on page 2 appear in most curriculum guidelines. However, no particular order or priority is given to the aims stated.

Although aims regarding the relation of science and technology to society and the world of work are usually included in the guidelines, curriculum resources and evaluation methods geared to these objectives are often unavailable. Any renewal of science education will require the development of appropriate teaching resources and methods of evaluation for each objective of science education.

The Planned Curriculum

In the absence of clear priorities for science education aims at the ministry level, school boards and teachers choose what objectives will be emphasized in the classroom. In general, the Science Council's survey showed that at the early and middle years, teachers stress the development of scientific skills and attitudes, and at the senior years, the learning of science content. Technology, the social context of science, or the history of science in Canada are not systematically covered in science courses, usually because of a lack of time, or because teachers feel that they do not have the academic training needed to teach with these emphases.

The Taught Curriculum

The Science Council's examination of 33 science textbooks showed that most of the texts in use stress only the learning of science content and the acquisition of scientific skills. A few at the middle level include material about the interaction of science, technology and society; however, most of the senior-level textbooks concentrate on the structure of each scientific discipline. Laboratory work prescribed by textbooks is highly structured and there are few opportunities for class discussion.

Eight case studies of science teaching indicated significant variations between ministry guidelines and classroom practice. Science at the early years is often taught without adequate facilities, and only rarely is a period in the timetable set aside specifically for the subject. At the middle and senior levels, the learning of science content is considered to be all that time allows. Preparation for further study is the aim most in evidence.

The study revealed a number of other problems. For example:

- most teachers of science at the elementary level are inadequately prepared for science teaching; 75 per cent have not taken a science course since high school;
- inservice education opportunities are, for the majority of science teachers, either nonexistent or of little value;
- many girls give up science subjects as soon as possible;
- students interested in science or who are particularly high achievers complain of a lack of challenge in science courses;
- most tests and examinations measure only how much scientific information a student has learned; other objectives are not evaluated and thus have little importance to students.

Opportunities for Renewal

Renewal in science education can and should build on existing strengths. During its study, the Science Council saw many examples of dedicated, innovative, and successful science teaching, curriculum development and teacher education (to note but three areas of science education) in every province and territory of the country.

Based on the study's findings, the Council has identified eight ways in which the renewal of science education can be initiated. These can be divided into three groups:

- Science education for all
- Redirecting science education
- Monitoring science education

Science Education for All

To ensure that *all* children receive an appropriate high-quality science education, the Science Council proposes three initiatives.

1. *Guaranteeing science education in every elementary school:* Science education should be provided for all children in elementary schools in Canada. It is already written policy. Now it must be put into practice.

Most children from kindergarten to the end of elementary school receive only a token education in science. The subject is relegated to a minor position: it is not taught by specialists nor is it given special facilities or scheduling.

Much needs to be done: training for teachers who have no scientific background; support for those who do teach some science; provision of adequate supplies and facilities; preparation of appropriate curriculum materials.

2. *Increasing the participation of young women in science education:* Measures should be taken by educators to ensure that girls have improved opportunities and greater encouragement to participate fully in science and technology education.

Parental attitudes strongly influence how girls see themselves in relation to science. Nonetheless, schools can help girls develop a positive outlook: the elementary curriculum should take the child's preschool experiences (or lack of them) into account; teachers can avoid classroom practices that reinforce male stereotypes; emphasis on the science-technology-society interaction can show that science has a human dimension; teaching materials, especially textbooks, can include accounts of the work of women scientists and inventors; career counsellors can make girls aware of the need to plan a career and of the opportunities open to them in the science and technology field.

3. *Challenging high achievers and science enthusiasts:* Students with a high ability or special interest in science and technology should have program provisions made to encourage and challenge them to further inquiry.

Some students need more challenge to reach their full potential in science education. Gifted children are one of society's most valuable resources and should not be neglected. Students highly motivated in science also need a stimulating program that encourages them to further inquiry. For these students, educators can provide enrichment programs or even, where appropriate, schools that particularly feature science and technology subjects within a general education program.

Redirecting Science Education

To reorient science education, the Science Council recommends the following initiatives.

4. *Presenting a more authentic view of science:* The view of science and technology presented to students should include historical, social and philosophical dimensions.

Teaching about the history of science and technology, particularly that of Canada, will show students how the social and political climate can determine whether scientific activity is valued or ignored, and whether the results of research are well used. Future scientists will gain a more realistic view of their prospective careers, and future citizens will develop more realistic expectations of science and technology and will be able to base their political and social decisions on a sound knowledge of how science and technology function.

Moreover, studying the history of science provides opportunities to reflect on scientific knowledge and promotes values such as respect for knowledge, humility, perseverance, cooperation, critical judgement, and striving for excellence.

5. *Emphasizing the science-technology-society connection:* Science should be taught at all levels of school with an emphasis and focus on the relationships of science, technology and society in order to increase the scientific literacy of all citizens.

The Science Council strongly believes that future citizens need to understand science and technology and the impact of both of these on Canadian society. This training needs to be given top priority at all levels of schooling.

Young children need to learn about science through experiences in their immediate environment. Junior high students can begin to appreciate that scientific activities give rise to choices; and making these choices involves value decisions on a personal and societal level. In the senior years, students can become more aware of public issues related to science and technology and of the political choices involved.

6. *Setting science education in a Canadian context:* Science education in elementary and secondary schools should take into account the Canadian reality. Every Canadian student should know some of the history of science and technology in Canada and appreciate the importance of Canadian science and technology activity at local, regional and national levels.

Canadian children learn virtually nothing about the accomplishments and impact of science in their own country. The Council believes that science should be set in a Canadian context that includes both historical and social dimensions. Students need to learn how science and technology have helped shape this country and about the landmarks in our scientific heritage.

7. *Introducing technology education:* Technology education should form a greater proportion of secondary school education for all students.

Education should be more closely related to the world of work, not only in the context of vocational training, nor simply for non-academic students, but in an intellectually challenging form designed for all students. Students must become more aware of the use of knowledge to satisfy human needs, and they must also learn the basic skills of technology.

Monitoring Science Education

If the educational system is to receive the support it needs, the public must be convinced that schools are performing effectively. To this end, the Science Council proposes one final initiative.

8. *Ensuring quality in science education:* Assessment techniques must be developed and implemented for all the objectives of science education to inform individual students about their progress and to monitor the effectiveness of provincial science education systems.

When achievement of educational goals is not measured, those goals are not valued by students, teachers or the public; this fact has been well documented. Most examinations and tests in science courses assess how much scientific knowledge has been acquired by the student. Consequently teachers and students treat the other objectives as unimportant extras to be attended to if time allows. And, as every teacher knows, time rarely does allow.

Tests must be designed to measure all the various science goals, even though progress towards some goals is difficult to evaluate. Of particular importance are assessment instruments to measure progress towards the development of creativity, problem-solving skills, and an understanding of the interaction of science, technology and society.

Strategies for Implementation

These recommendations are the central conclusions of the Council's study. But changes in education are often agreed to in principle, even stated in government policy, and yet fail to become established in practice. It is not enough to agree on *what* needs to be done; strategies for *how* to effect change are also needed so that the efforts of many individuals and groups can be effectively deployed. Accordingly, the Science Council presents 47 specific suggestions for facilitating the renewal of science education. These are arranged in seven groups as follows.

Curriculum Leadership: Ministries of Education

Ultimately, responsibility for education lies with the ministers of education and any process of renewal must be sanctioned and encouraged by them. Among 13 recommendations directed to the ministries are the following:

- increasing the proportion of time spent on science at elementary school to 15 per cent (45 minutes per day);
- developing technology courses for secondary schools;
- setting up an inter-provincial test-item bank;
- requiring all students to take science until grade 11.

Curriculum Leadership: School Boards and Schools

School boards are responsible for the implementation of ministry of education programs and for operating the school systems. The report contains five recommendations for this level, including:

- setting up, where numbers warrant, high schools of science and technology.

Human Resources

Of crucial importance to science education are the number and quality of science teachers. Among the 12 recommendations related to teachers and teacher education are:

- subject-specific teaching certificates;
- school-focussed inservice education programs;
- improved planning of preservice teacher education by universities;
- special summer institutes to upgrade elementary school teachers.

Instructional Resources

Teachers must have the necessary tools for science teaching. The Science Council has five recommendations in this area. These include:

- a Canadian foundation for science and technology education to help develop new curriculum materials;
- a centre for research and development in computer-aided learning.

External Resources

Many organizations and groups outside the school can support the work of science teachers. The Council makes nine suggestions including the following:

- a federally sponsored national information program stressing the need for young women to participate in science and technology;
- a program of awards for excellence in science education to be offered by the Royal Society of Canada.

Research Resources

Several of the Science Council's recommendations require further research. The report contains three recommendations in this area including:

- an interprovincial network of researchers who study methods of teaching about science, technology and society.

The major thrust of these strategies is towards facilitating renewal of science education at the classroom level. Renewal must be rooted in the schools, it must be linked to the professional growth of science educators, and it must be supported by the public and outside agencies with a concern for science education.

The 47 recommendations contained in the report are concrete, practical and immediately applicable. Their implementation is essential if science education is to succeed in preparing Canadian students for tomorrow's world. Educators cannot act alone: only in a climate of support and cooperation can renewal become a reality.

The report summarized here, *Science for Every Student: Educating Canadians for Tomorrow's World*, is the product of a four-year study by the Science Council of Canada of science education in elementary and secondary schools.

The study, conducted with the cooperation of the Council of Ministers of Education, Canada and the science teaching profession, had three phases. The first, issue identification, entailed critical reviews of contemporary science education by well-informed observers. The issues raised provided an agenda for the research and deliberation that followed.

The research phase consisted of four major projects: an analysis of science curriculum policies from all provinces and territories; an analysis of 33 commonly used science textbooks; a survey of more than 4000 science teachers; and eight case studies of science teaching in schools in all parts of Canada. The results of this research program constitute a substantial database of Canadian science education and are published in Background Study 52, *Science Education in Canadian Schools*.

In the third and crucial phase of the study, more than 300 individuals - ministry officials, school administrators, teachers, university faculty, employers, trade unionists, parents and students - came together in a series of 11 deliberative conferences to debate future directions for science education in their province or territory. Their discussions and suggestions for what needs to be done to renew science education provided the Science Council a firm base on which to prepare this report.