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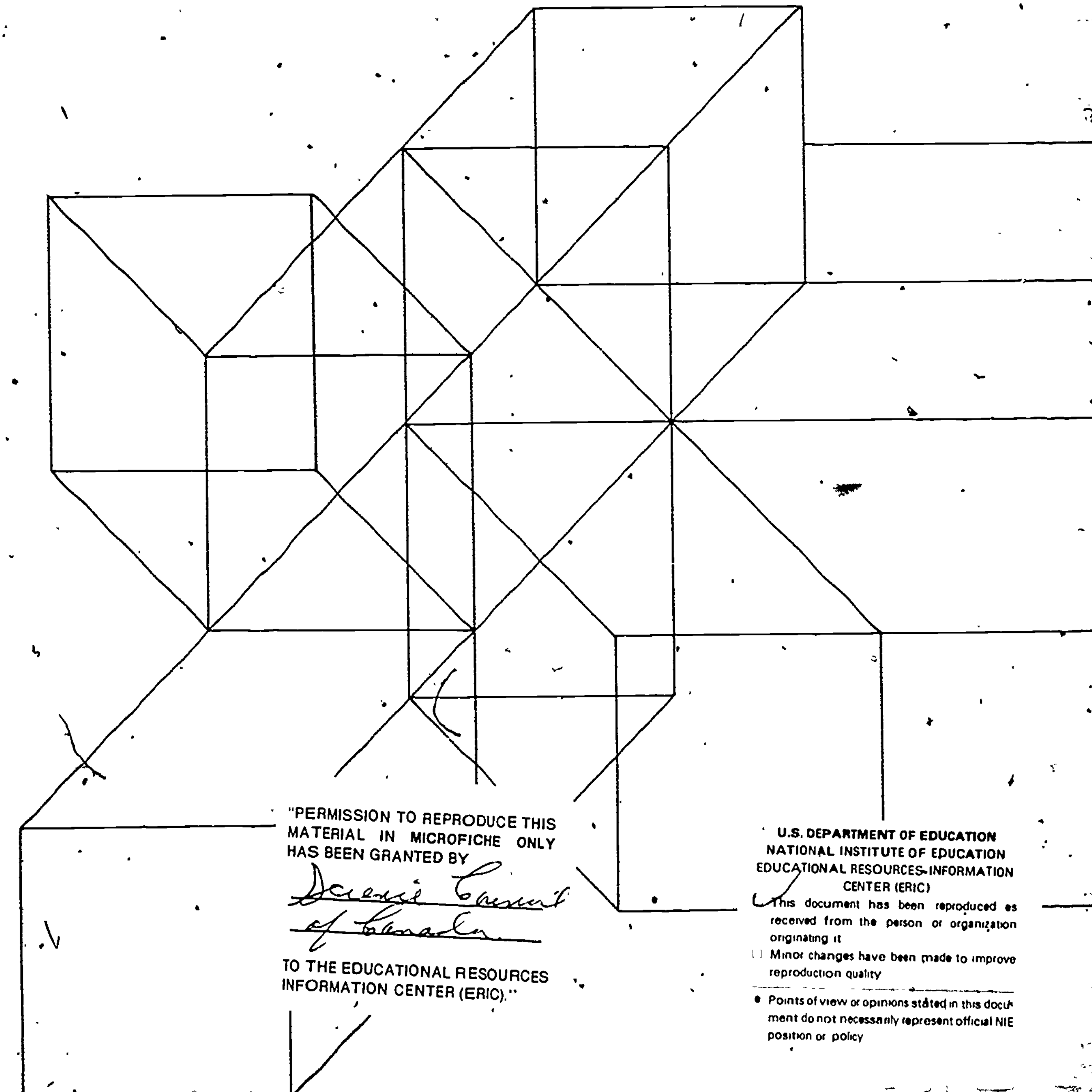
ABSTRACT

Proceedings are presented of a symposium on science education in Quebec, which was sponsored by the Science Council of Canada and the Association des Professeurs de Sciences du Quebec. Papers and authors addressing the background and present state of Quebec science education are as follows: "Science Teaching at the Secondary Level: An Evaluation" (Louis Ste-Marie); and "Science Teaching: An Answer or a Question?" (Marcel Risi). In addition, comments are offered by Graziella Levy concerning developments at the secondary and primary levels and by Alexander Liutec concerning the present and future situation of science education in the English sector. Future directions for science teaching in Quebec are addressed in "What Sort of Scientific Education for What Sort of Society?" (Jacques Desautels). Graeme Welch also discusses the future directions for science education and suggests that science teachers must assume responsibility for reinforcing linguistic, mathematical, and cognitive skills development of students. Future directions in Quebec are also addressed by Germain Gauthier, who identifies some important characteristics of the social and educational environment in Quebec and outlines possible approaches to science education. The topic of popularization is discussed by Pierre Sormany with regard to the accuracy of scientific subject matter in popular texts and approaches to interest students in science. A concluding statement by Gilbert Lannoy summarizes the scope of the comments and papers presented in the symposium, and additional summaries are presented of these presentations and of discussions. Appended materials include a symposium program and a paper, "Science Teaching in Quebec. Why? For Whom?" (Raymond Duchesne). (SW)

Québec Science Education: Which Directions?

Science Council of Canada



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FOREWORD

In the wake of the increasing criticism being made of science education over the past few years, and the concern about how well science is being presented to primary and secondary school students, the Science Council of Canada launched a major study on science education in October 1979. The Council of Ministers of Education, Canada, after welcoming this initiative, demonstrated its willingness to cooperate in each phase of the study. In addition, we are pleased by the considerable interest and participation shown by the country's science teachers' associations. The symposium held jointly under the sponsorship of the Science Council and the Association des professeurs de sciences du Québec (APSQ) on 7 March 1981 in Montréal is a good example of this cooperation.

In a society where science and technology determine a large part of the way we live, science education deserves particular attention. More than ever, decisions affecting its course must be made using well-grounded research based on information gathered from all those who play a direct or indirect role in science teaching. The collection of this information, along with the deliberations that may ensue, are two major objectives of the study. The symposium was a natural element of this strategy; its purpose was to highlight diverse points of view on science education in Québec while permitting the participants to examine the history of science teaching, its current situation, the questions that arise, and future possibilities.

The symposium participants identified a great variety of critical issues. Not surprisingly, all agreed on the need for change, without agreeing on concrete recommendations. The organizers had not expected any unanimous agreement on the orientation of science education. They had deliberately structured the symposium so as to stimulate a series of ideas, and it will be apparent to the reader of these proceedings that this objective was achieved. The discussions even trickled out of the symposium itself, as evidenced by the press accounts that followed; as an example, we have included an article with an original perspective, by Raymond Duchesne.

The organization of symposia comprises only a part of the activities undertaken by the Science and Education Study. Several new discussion papers are currently being prepared for publication, a large questionnaire survey of science teachers is underway, and a series of case studies is commencing. Those who are interested in further information regarding these activities are invited to communicate with us.

Finally, on behalf of the Science and Education Committee, I would like to thank all those who gave presentations at the symposium and those who actively participated. I would also like to thank Mr. Claude Marineau and Mr. Gilbert Lannoy, the President and the Director of Information of the APSQ respectively, as well as Mr. Jean-Pascal Souque and Mr. Paul Dufour, both of whom were responsible for the organization of the symposium and the preparation of these proceedings.

Maurice L'Abbé
Executive Director
Science Council of Canada

I. PERSPECTIVES ON THE BACKGROUND AND PRESENT STATE OF SCIENCE EDUCATION IN QUÉBEC

Science Teaching at the Secondary Level:
An Evaluation

by Dr. Louis Ste-Marie
Faculté des sciences de l'Éducation
Université de Montréal

In 1972 a research team was formed at the Faculty of Education of the Université de Montréal for the purpose of evaluating science teaching at the end of the secondary level and where appropriate, the beginning of the college level. The team was christened EVALENSCI, an acronym for "évaluation de l'enseignement des sciences."

At the time, the majority of the programs and methods used in science teaching were adaptations of American products of the 1960s. Furthermore, regardless of the textbooks used, the teaching and learning of science were presenting serious difficulties for teachers and students.

In the beginning, the team agreed on a synthesis of the goals of science teaching that were already contained in the programs of the Department of Education, the recommended textbooks and other publications on the subject. Three groups of goals were selected. The first two are directly related to science teaching. The third, related only indirectly to science teaching, is nevertheless of considerable importance in the context of education today.

The first objectives are those which contribute to the development of the student's intellectual independence. These objectives are concerned with cognition that goes beyond the mere acquisition of knowledge to the encouragement of certain habits of thought appropriate to scientific reasoning (such as critical judgment), and which in general could be termed a "scientific" thought pattern. At the same time, there is also the concern with developing the so-called "scientific" aspects of creativity, such as problem analysis, the formulation of hypothesis and the ability to change one's ideas.

The second objectives to which science teaching contributes directly are those intended to facilitate the integration of the student into society. This is a matter of developing scientific attitudes, awakening interest in science, and encouraging skills that will facilitate adaptation into a society increasingly influenced by science and technology.

Finally, objectives that deserve careful attention are those related to the social and emotional development of the student, even though science teaching makes only an indirect contribution to this process by encouraging self-awareness, motivation, satisfaction in the course and self-confidence.

The data used in the team's studies were collected during 1973-74. They were gathered from a sample composed of the population of the seven regional school boards surrounding Montréal Island, where there is a great diversity of socioeconomic backgrounds. The sample was chosen at random by the teachers of each science program at the secondary IV level* (2 biology programs, 2 chemistry programs and 3 physics programs). It included 46 teachers teaching 4272 students in 143 classes. Fifteen different tests were used to collect the data, which made possible measurements of 40 variables.

I do not intend here to go into further details of the methodological procedures used in this research project. Some of the studies have already been covered in articles published in various educational periodicals. A final report has been submitted and is available from the Service de la recherche universitaire, Direction générale de l'enseignement supérieur, Ministère de l'Éducation à Québec. An article summarizing the project will appear shortly in the Revue des sciences de l'éducation.

My main aim today is to present an overview of the results in an attempt to derive from them the principal messages. Without going into detail about each area of research undertaken by the EVALENSCI team,

* In Québec, the elementary level consists of six years of education, after which each consecutive year is labeled secondary I, II, III, IV, V. Secondary IV, for example, would correspond to grade 10 in other provinces.

the following are broad outlines of the conclusions and directions. The overview is presented within the framework of the groups of science teaching objectives cited above.

Objective: The Integration of the Student into Society

Even though we live in a world in which our comfort, our health and even our economy are dependent on science and technology, even though we are confronted every day by an environment that is influenced totally by the application of science, and even if science teachers are convinced of the importance of science in society, science education, with its curricula, textbooks and methodologies, has not succeeded in making secondary school students aware of the human and social values of science. Study of the sciences does not elicit from them an attitude favourable to the nature and purposes of science; on the contrary, it even discourages potential candidates for a scientific career. Science, in their eyes, has lost its intellectual and social prestige.

This is a general finding. The research, the results of which are summarized below, provides specific evidence and adds nuances that help in understanding this vision of science teaching in Québec.

Satisfaction with a course is reflected in an interest in the subject matter, enthusiasm for study, greater success and a favourable attitude to the course. Poor satisfaction is reflected by an interest that is quickly exhausted, less success with the course, a lack of appreciation for the subject matter, poor enthusiasm for study, and a less favourable attitude. An examination of the overall attitude of students towards their science courses shows that it changes in the course of the year, becoming less positive as the students fail to find in science what they had hoped. Of all the subject matter, physics is perceived with the least favour.

This overall attitude includes the students' perception of the importance of the course, its difficulty and the interest it arouses. These three elements were subjected to separate studies.

All students regarded their science courses as important, regardless of the subject matter or the curriculum. Even those students who dropped the course recognized its importance.

At the beginning of the year, physics was regarded as the most difficult subject, and this remained true for the year. Biology, however, which at the beginning of the year was regarded as easy, soon came to be seen as more difficult than anticipated.

Interest in science courses was subject to more complex variations and is worthy of greater attention.

Biology, relatively speaking, is the subject that aroused the greatest interest, while physics aroused the least. However, students lost interest in all science subjects over the course of the year, especially chemistry. This decline of interest in science was in direct relation to the number of courses taken: the more science courses the student took, the sharper the drop in interest.

A special study of this phenomenon was conducted in physics, because of the greater variety of programs offered, such as PSSC, DGL, BGL and HPP.*

Science teaching aims to impart a scientific culture to all students, whether they be future scientists or not. Those who have no intention of going into a scientific career are people-oriented, whereas those who are planning a scientific career tend to be object-oriented or oriented towards natural phenomena. The two groups were distributed evenly throughout the various physics programs and demonstrated a similar degree of interest in the study of science at the beginning of the year. By the end of the year, however, the object-oriented students had maintained their interest, whereas there was a

* PSSC (Physical Science Study Committee), DGL (Désautels, Guay, Legendre), BGL (Benoit, Gauthier, Laberge), HPP (Harvard Project Physics).

perceptible drop in the interest of the people-oriented students, regardless of the program taken. In other words, not even the HPP physics program was able to get through to them, even though it was developed to provide a general science education to students who were not science-oriented. The lack of interest is accompanied by a drop in performance on the part of the students.

Objective: The Social and Emotional Development of the Student

It is often stressed that the student's motivation should influence his or her performance. Motivation to study is born out of a need for security, for esteem or recognition of the individual's worth by others, and out of a need to acquire a humanizing culture which provides an inner satisfaction. Before everything else, security must be achieved. In physics, our study found that students did not feel secure and that this had a detrimental effect on scholastic performance. Abstract presentations, low grades and excessively difficult examinations, did nothing to encourage the students to feel self-confident or secure about being promoted. It is hardly surprising to see a loss of interest in science and in motivation to work, and that many students simply dropped their courses.

It should be noted that this disillusionment with science was due, not to the subjects themselves, but to the courses, or in other words, to the teaching.

Attempts have been made to improve the teaching of science. One teaching method, Keller, is centred on the person and on individual work supported by peers acting as tutors; it has been used to try and encourage the personal growth of the student, primarily at the outset of college physics. It was found that students taking optional science courses were less aware of their own potential and of the development of their own personality than students in the humanities and the arts.

This teaching method enabled science students to draw level with their colleagues in the humanities in terms of their awareness of their value and potential. It required the student to work more intensively, but he/she achieved better results for less time devoted to study than students in traditional courses. The method also promoted a pleasant work atmosphere and gave the student a great deal of satisfaction.

Science teachers have tried teaching by objectives. The number and frequency of evaluations of the objectives over the long term are annoying to students and the effects of this annoyance are reflected in the course as a whole. Teaching by objectives fails to change the loss of favour suffered by science courses.

Much opinion supports laboratory work and the conducting of experiments. This activity encourages individual work and is supposed to give the student a greater degree of satisfaction in the learning process. Our study shows the deciding factor is not the number of experiments, but the intensity of the individual activity outside of the experiments themselves. Some recent programs, such as BSCS (Biological Sciences Curriculum Studies) have integrated laboratory work into the presentation of the subject matter and succeed in giving the student a greater degree of satisfaction than do traditional programs.

However, the frequency of laboratory sessions also influences the degree of satisfaction with the course. The greatest satisfaction is found at the opposite extremes of the frequency ladder: few laboratory sessions (less than one per month) and many laboratory sessions (two or more per week). The least amount of satisfaction was found at a level of one laboratory session every two weeks. This phenomenon might be explained by the theory that infrequent experiments tend to be well prepared and thus satisfying to students, whereas frequent experiments are interpreted by students as a sign that the experiments are more important than classroom course content and, as well, they allow the student to be more active in his or her acquisition of knowledge, which brings the student satisfaction. Why one laboratory session every two weeks is least satisfying still remains a mystery. The intensity of laboratory activity is not related to the frequency of laboratory sessions; perhaps this particular frequency is associated with greater demands - for example, the required laboratory report - and this cools the student's enthusiasm.

Objective: Development of the Student's Intellectual Independence

A large number of science programs based on the scientific process have appeared in Québec since 1960. It was hoped that students would acquire scientific work habits, which implies learning various skills that reflect scientific method: rigour and creativity. Because "rigour" is the quality that is stressed a great deal, our research concentrated primarily on creativity, which calls upon the ability to be aware of problems, to formulate hypotheses concerning cause and effect, and to question conventional wisdom.

Our findings showed that creativity increased over the course of a year, although it was not influenced by any textbooks, either modern or traditional.

In general it can be said that modern textbooks have not fulfilled all the hopes vested in them. They have had little effect in arresting the decline in interest in science courses and have not provided a vehicle for offering all students a scientific culture; they have had no more success than traditional programs in imparting the scientific method or even basic concepts. However, they have been successful in making students reject false concepts of science.

Conclusion

To summarize the findings even more succinctly, we can say that "the development of the student's intellectual independence" has not been a complete failure. Progress has been made over the course of the academic year in the acquisition of scientific reasoning. Those programs that were specially designed to aid this process were, however, no more successful in the attempt than others.

The objective of "facilitatng the social integration of the student into society" has, on the other hand, not been reached. Except among those students already science-oriented, the role of science in society dropped in prestige and respect and the study of science suffered from a loss of interest. Programs designed specifically for students who were not science-oriented were no more successful than traditional ones.

The teaching of science did not in general contribute to students' emotional development. Motivation to study and satisfaction with the course remained low. We noted that this aspect could be improved by presenting materials oriented towards the individual.

An Explanation

Does science teaching at the secondary level make too great an attempt to impart science without emphasizing its relevance to society in general? Is too much stress laid on presenting a "culture" that is too specifically the preserve of one group of society, namely scientists? As it is, students are assumed to be, either now or in the future, a part of this group, and they are taught to act and think like scientists. Does the same thing happen with other subjects? The attitudes and values of various groups such as business people, artists, philosophers and so on are passed on in schools as well, but what happens to culture in general? Who is to undertake the synthesis of different viewpoints that have been compartmentalized by subject?

There was a time when the sciences were searching for their place and striving for acceptance in our society. Today, they have found their place. Their effects (both negative and positive) on culture, our way of life, ideas, recreation, health, the environment and economic and political life are noticed. Science is an established part of the social landscape.

The school, however, provides no more than a visit inside the temple of science. It is not sufficient to look out of the windows from time to time and observe the effect of certain scientific discoveries. We have to open the doors and go outside to see science in its natural and social environment. We have to interest every student in science and in its effect on culture and society. In order to do this it is not sufficient (and for some students it is not even necessary) to visit the temple of science intensively. The important thing is to place the temple appropriately in its natural setting.

Suggestion for the Future

I cannot resist making one particular suggestion for the future.

I believe that we must envisage a course that will be quite different from those that exist at present for students who are not science-oriented. I would suggest that this be a course in the "history and sociology of science." It should be neither a history of scientific discoveries nor a history of scientific research, but rather a history of the achievements and techniques of science, emphasizing their influence on social life, ideas, customs and so forth. This would serve to present science in a more humanistic light. I believe this course would also make a cultural contribution to those heading towards scientific careers.

We have been talking about a course like this for a long time. It is high time we did something about it.

Mrs. Graziella Lévy

Pedagogical consultant for elementary science
Commission scolaire Taillon

The topic of the roundtable discussion to which I have been invited, "Perspectives on the Background and Present State of Québec Science Education," stirs many personal memories and prompts me to reflect on several issues.

The memories are those of experiences I have had in the world of education, and the reflections concern both the past and the present situation.

Prior to the 1970s, the students had a textbook from which the teacher took course material and on which the curriculum was based. Scholastic success was in large measure a function of the equation:

knowledge=textbook

which in school terminology was known as learning.

The textbook constituted a point of reference accessible to all concerned, including parents.

The 1970s in Québec were fertile years for new science programs in chemistry, physics, biology and the natural sciences. These were framework programs that expounded a philosophy, listed contents and indicated methods.

What is Happening at the Secondary Level?

The students are issued a new textbook, this time one with a guide to practical exercises.

The teachers are sent to more or less hastily organized retraining courses and, lo and behold, the reform has been accomplished.

Everything has changed in the sciences from one day to the next: the content, ways of teaching and learning; it doesn't matter, anyone can do it. However, anyone can't do it, and the old equation no longer provides a guarantee of success; the content of the textbook is no longer the determining factor, the rule has to be changed.

No sooner said than done: a miracle equation is adapted by simply substituting "method" for "textbook":

knowledge=method

This rule applies equally to the teacher and the student; however, a "method" is not a point of reference accessible to all concerned, and the parents in this case are not necessarily the most disadvantaged. No one knows exactly what is being substituted for the old "knowledge," nor exactly what the aim of the framework programs is; there is some difficulty in interpreting and applying them.

Against this background of lack of understanding and ability, and of questions which are either not formulated or which go unanswered, criticism is easily directed against these new sciences. People disapprove of them and ultimately believe they are rejecting them because they have been imported.

At the primary level, the 1970s saw the appearance of a natural sciences program that used, and then dropped, the word "environment." This is also a framework program - it spoke of method, but exalted the acquisition of skills and the development of attitudes.

The Québec Department of Education has given its approval to four methods, one of which originated in Québec. I do not wish to express a value judgment here on these methods, which at least have the advantage of providing a security blanket for teachers. The publishing firms were quick to organize sessions to familiarize teachers with their material and school boards hastily hired counselors.

For good or ill, these professionals were given the task of bridging the dual scientific and educational void of the teachers assigned to them. No one has yet succeeded in accomplishing this enormous task.

At the primary level, the equation could be expressed as:

knowledge=skills

The nature of a skill and how it is acquired is by no means clear to everyone involved, and it is indeed a rare parent who recognizes as science what their child does at school.

In the meantime there is a great deal of talk about the crisis in the sciences. On all sides one hears the situation in the sciences is "bad," that secondary school students are staying away from science courses, that parents consider such courses useless at both the primary and secondary levels and that teachers either fail to teach or teach badly.

We are now in the 1980s and see that new curricula are being developed. Instead of framework programs, the curricula for the 1980s propose learning objectives.

Scholastic success is thus ultimately assured, since the student has only to satisfy the equation:

knowledge=objectives

To sum up, may I say here that the dogmatism of the objectives has replaced the dogmatism of the textbooks and that of the methods.

If we assume that curricula are tools adapted to the evolution of education, we can ask ourselves why all these changes are so radical, not to say spectacular?

Perhaps it can all be traced back to the 1960s.

Students rejected classroom teaching; virtually everywhere in the world they protested against the system in general and this protest ricocheted back on the schools.

As far as science in particular was concerned, the dizzying progress of the previous years had produced a gulf between school and life.

In the turmoil of change, the focus was on the sciences. The world was obsessed by the terrifying rapidity of scientific and technological discoveries, and the educational system had to take this fact into account while making up for considerable lost time.

The challenge was to invent a teaching method that would also be a learning method, because knowledge was in danger of becoming obsolete before the student could make use of it.

Science education should set a premium on information and should begin as soon as possible, from the first day at school.

The United States is allocating human and financial resources on an impressive scale to reform science teaching.

These enormous projects are producing philosophical and methodological statements, with widespread impact. The American methods are being welcomed in the industrialized countries, and Québec welcomes them as well.

The sciences, instead of remaining descriptive, are becoming experimental; teachers, no longer simply repositories of knowledge, are becoming classroom animators; the classroom itself is changing from a row of seats to a laboratory.

It is hardly surprising that the sum of these changes should be called a "revolution"!

The curricula of the 1970s relfected this.

How did the students, teachers, parents and observers feel about this revolution?

Do the changes of the 1980s constitute a new revolution? Progress? A regression?

I hope that an in-depth scientifically conceived study will be carried out before the curricula are changed again, perhaps in the 1990s.

Let us turn our attention again to the current situation. Budget cuts, reductions in the number of hours allocated to science teaching, optional science courses, disaffection on the part of students and parents: these are the well-known problems.

I would nevertheless like to cover a point that is often ignored: the training of teachers. To what extent do our teachers feel capable of implementing the framework programs and the objectives-oriented curricula?

My concern is primarily the elementary level, where it is safe to assume the majority of the teachers have taken no science courses since high school; that the courses they have taken are traditional science courses, and that most of them have had no contact with practical experimentation, have never had a course in experimental or participatory teaching methods, and have never had to evaluate the learning value of an experimental course.

It is nevertheless claimed these teachers are capable of giving an introductory science class based on the biological, physical and technological environment.

Do we still believe in miracles? That a curriculum alone is sufficient to guarantee the quality of the learning experience?

Will we not see rather that science courses are failing in their real purpose - that of preparing students to live in a world that is different from the one their parents knew and perhaps even from the one their elder brothers and sisters knew, to train their minds to reason, to exercise judgment and to make decisions?

I cannot help wondering about the present and future situation of science teaching in Québec. I cannot get out of my head the image of an amputee forced to walk without crutches.

Despite this, I also have before me a mental image of those classes of enthusiastic children that I have seen bending over tadpoles, gerbils and ice cubes and discovering that they too are partners in this planetary vacuum jar of ours!

I can also see those teachers who tried and succeeded in inspiring a new kind of class: nature classes on the periphery of the school, an indoor gardening activity, a session of measuring the volume of liquids; teachers who tried and succeeded in accepting the new sciences with all the demands of intellectual and material preparation.

A very high proportion of these teachers believed that science teaching was beneficial for the harmonious development of the child and abandoned their distrust of science with a capital S, showing in the process the kind of interest it was easy for students to imitate.

There can be no doubt that a disinterested teacher will not have a class that is greatly attracted to the sciences.

Before concluding, I would like to mention the large number of parents who asked to be informed about the new sciences, and who visited the school so that they could get to know at least a small portion of what their children were experiencing.

I will now conclude with the following message to teachers: you are the craftspeople of education, and you are the ones on whom we count so that the child can experience the wonder and fascination of science at the elementary level, so that the adolescent can be attracted and shaped by science at the secondary and college level, so that tomorrow's adults will not feel alienated in a world constantly evolving, and so that today's adults will be convinced of the benefits that the study of science will bring to their children.

Mr. Alexander Liutec

Vice-Principal
Chambly County High School

Introduction

It is an honour and a pleasure for me to have the opportunity to review the present situation of science education in the English sector, and also to look at the future. I will attempt to do this by very briefly reviewing the science program of the late 1940s and early 1950s from a student's point of view. Throughout the 1960s and 1970s I have had the opportunity, as a teacher, a science consultant and a school administrator, to see the development and implementation of some of the newer programs.

Traditional Years - Late 1940s and Early 1950s

It is very difficult to describe precisely the kind of science programs that were being offered to the students during this period. Traditionally, however, the role of the laboratory in science teaching at the secondary level was a limited and somewhat unimportant one. In the public system, some "experiments" were usually carried out, but instructions and questions in the experiments were such that the activity became merely an exercise in which the students searched for the right answer. In some schools this situation frequently deteriorated to the point where a significant number of students came to the laboratory with their laboratory reports already completed. This was accomplished by carefully reading the textbook to find out what they were supposed to have learned in the laboratory, or by deducing answers from the questions. In the laboratory the student merely collected some data which fit the questions and answers.

Too often, science at the secondary level was a read-about, tell-about, teacher-demonstration oriented course with little or no individual laboratory work. Even when simple experiments were proposed, step by step instructions were given, and the student was told exactly what to find out; little credibility was given to the student's ability to make observations that would serve as evidence. Students were expected to find certain results and were told when they were right or wrong. In such an environment, secondary science became a memorization of facts stated by the teacher who expected the student to reproduce the same on demand.

This condition existed as a rule in secondary schools in spite of the fact there was a well-defined curriculum and sequence of science courses. (Chart 1)

For example:

a) A one-year general science program was offered in grades nine or ten. This program contained many practical experiments, both in chemistry and physics.

b) A two-year chemistry program was offered in grades ten and eleven. This program was designed to stress the practical aspects of chemistry.

c) A two-year physics program was offered in grades ten and eleven. This program included a good deal of laboratory work.

d) A one-year biology program was offered in grade eleven.

In addition, some school boards offered a grade twelve program where chemistry, physics and biology were expanded to include additional or more advanced topics.

The school where some or all of these courses were offered had well designed and constructed science laboratories, preparation rooms and lecture rooms. Teachers put in a great deal of time and effort to ensure that their laboratories were always in good order. There was a friendly relationship between science teachers in the universities and the secondary schools. McGill and Sir George Williams (Concordia) University professors were involved directly in the curriculum development and its modification and also in the preparation of examinations for the provincial or university entrance examinations. During the annual Teachers' Convention, teachers would meet to discuss any changes in the curriculum or any difficulties that students may have encountered while writing examinations.

Experimental Years - Late 1950s and 1960s

In the late 1950s and during the 1960s there was a tremendous excitement created in the educational system by the publication of the Parent Report on the state of the educational system in Québec and by some of its recommendations.

These recommendations resulted in:

a) the appointment of a Minister of Education and the development of a new, but dynamic, department of education;

b) the reorganization of the school boards. Elementary and secondary schools were reorganized so that the elementary school became K to 6, and the secondary school became 1 to 5;

c) new and large comprehensive secondary schools being built throughout the province;

d) the beginning of computer timetabling;

e) the beginning of multiple-choice examinations - machine scored;

f) a new system of postsecondary education being established.

During this period many science curriculum reform projects at the secondary level did a great deal to change the role of laboratory work in science courses. By carefully developing unique and challenging experiments, these curriculum projects in the life and physical sciences helped re-establish the laboratory as central to the science courses. At their best, the programs resulting from these curriculum reform projects encouraged the student and teacher to consider the laboratory as the place where evidence was obtained and used for the development of science concepts. The Biological Science Curriculum Study (BSCS) stated the concern:

"The Education Committee of the American Institute of Biological Sciences had expressed concern over the state of biological education in the United States. With support from the National Science Foundation, it established the Biological Science Curriculum Study, composed of distinguished biologists and educators, and with consultative help from a wide variety of disciplines, in an attempt to restructure the discipline in such a way as to prepare students to cope with the biological problems faced by the simple fact of being a living organism."

From ChemStudy one can see the new approach:

"Chemistry - Experiments and Principles presents chemistry as it is today. It does so with emphasis upon the most enjoyable part of chemistry - experimentation. A clear and valid picture of the steps by which scientists proceed is carefully presented and repeatedly used. Unifying principles are developed, with the laboratory work providing the basis for the development."

From Harvard Project Physics (HPP) one can read:

"The challenge facing Harvard Project Physics was to design a humanistic course that would be useful and interesting to students with widely different skills, backgrounds and career plans. In practice, this meant designing a course that would have the following effect:

1. To help students increase their knowledge of the physical world by concentrating on ideas that characterize physics as a science at its best, rather than concentrating on isolated bits of information.

2. To help students to see physics as the wonderfully many-sided human activity that it really is. This meant presenting the subject in historical and cultural perspective, and showing that the ideas of physics have tradition as well as ways of evolutionary adaptation and change.

3. To increase the opportunity for each student to have immediately rewarding experiences in science...."

The Physical Science Study Committee (PSSC) states that:

"Physics is presented not as a mere body of facts but basically as a continuing process by which men seek to understand the nature of the physical world."

Throughout the history of secondary science education many efforts have been made to improve science teaching by rethinking and restructuring what was taught. The 1960s were a period of accelerated evolutionary change in secondary science education throughout North

America. While Americans were investing a great deal of money and human talent in developing new approaches to the teaching of sciences and writing new textbooks, Québec science teachers, with a great deal of help and encouragement from the Department of Education, were evaluating some of the new programs and, at the same time, were rethinking some of the traditional ones. As a result, by the late 1960s and early 1970s there were enough science courses to capture the imagination of the most talented student and to meet the minimum requirements of all the students in the system.

Chart 2 and Table 1 show the sequence of science courses in the elementary schools, from K to 6, and in the secondary schools, from 1 to 5. One can see that there are two obvious streams:

a) an academic stream where students concentrate on, for example, languages, mathematics and sciences; and

b) a general stream where students would opt for a more general education and perhaps go through the technical-vocational area.

Table 2 shows the number and percentage of students who were registered to write these examinations, as compared to the number registered to write English 422 Composition (secondary IV) and English 522 Composition (secondary V). From this table it can be seen that the percentage of students taking a one-year course is considerably greater than those taking a two-year course.

For example:	PHY 512	41.2%	PHY 552	9.8%
	CHEM 442	43.6%	PHY 522	2.8%
	BIO 412	27.3%		

Conclusion

After fifteen years of planning, developing and modifying, our Department of Education came up with a very impressive sequence of science courses for its secondary system. This list indicated there are enough courses at each level to motivate and inspire every student. However, no sooner had this list been produced than the following statements were being made:*

"Québec students will be doing more reading, writing and arithmetic under curriculum reforms proposed by Education Minister ... Everyone in Québec society - and elsewhere in the world - agrees that in the kind of world we live in, students must be given a better foundation."

According to the proposed Régime Pédagogique of November 1980, we may be returning to the 3R's, but that will not relieve the boredom and unrest among our students.

With all the planning, developing, and implementing of new programs, serious problems continue to exist, as one student pointed out in a letter to the editor:

The School System is the Source of the Problem

"It was with mixed feelings that I read your February 18 article entitled 'School bomb work of pranksters.'

"As a law-abiding high school student, I feel it is my moral duty to condemn the so-called 'pranksters' as no-good juvenile delinquents. However, at the time, I must reluctantly admit that I fully understand the frustration these students feel and the motives behind their acts of destruction.

"The bomb that racked Chomedey Polyvalent is not unique to Montréal-area high schools.

"Similar bombs of more complex construction have plagued North American schools for years. To construct these weapons requires a detailed knowledge of chemical and physical principles.

"It should be obvious that the students responsible for these acts of aggression are not stupid; rather, they are probably bright individuals who feel intellectually and creatively stifled by the conventional school system.

"It is becoming apparent that what is desperately needed in our secondary schools is a program whereby students would be able to channel their knowledge and aptitudes into constructive projects.

* Montréal Gazette, 27 February 1981.

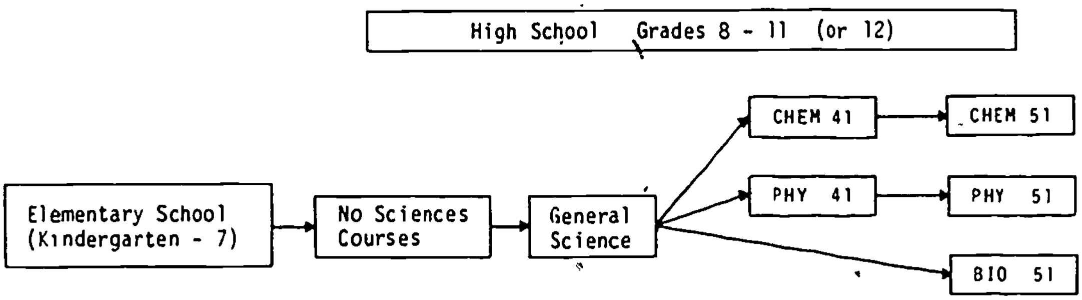
"He or she has no place to channel energies and interests. This obviously leads to boredom and resentment on the part of the student towards the school system which, in extreme cases, can eventually lead to violent acts of wanton destruction.

"I do not condone the actions of these students. I merely point out to school authorities that the solution to the problem of student boredom and unrest lies entirely in their hands.

"A positive course of action will be sure to bring favourable results, transforming our high schools into safer and more richly rewarding centers of learning for both students and teachers alike."*

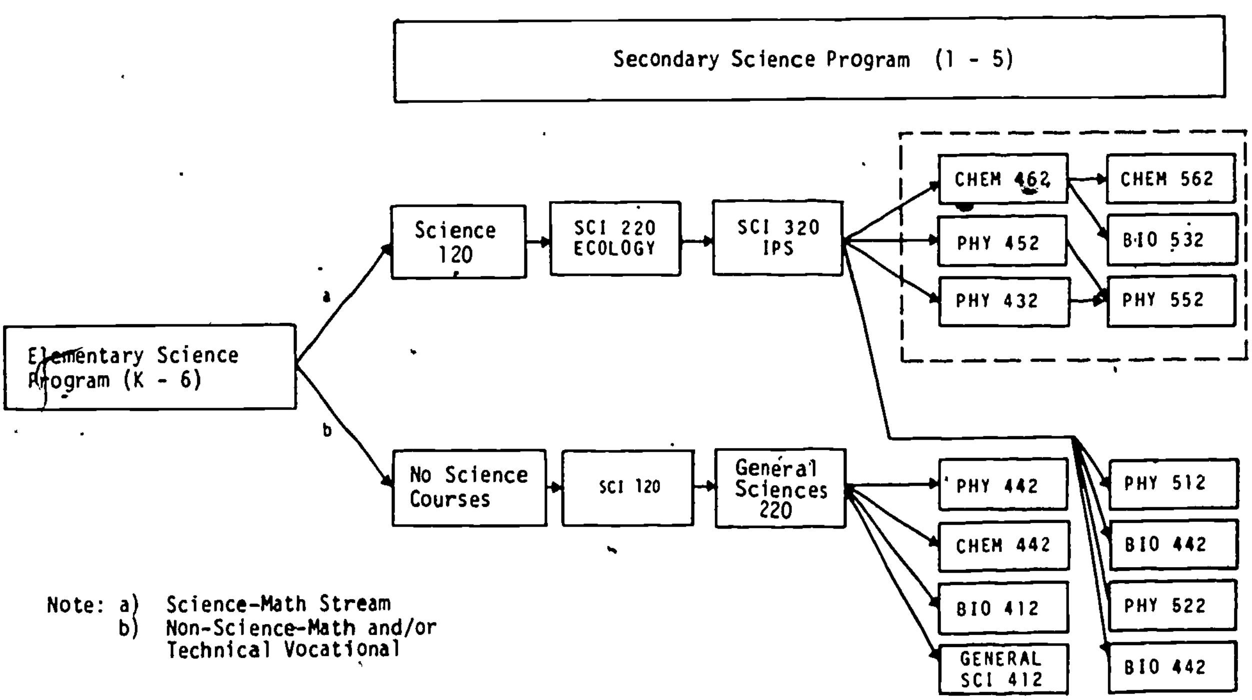
* Letter in Montréal Gazette, 27 February 1981.

CHART 1: SEQUENCE OF SCIENCE COURSES - 40's AND 50's
QUEBEC, ENGLISH SECTOR



Note: Seven years of Elementary followed by four of five years of High School

CHART 2: SEQUENCE OF SCIENCE COURSES IN
ENGLISH SECTOR 1980



Note: a) Science-Math Stream
b) Non-Science-Math and/or Technical Vocational

Table 1 - Sequence of Science Courses in Secondary Schools (Public Sector)

Level		Description
I	SCI-120	Physical Science
II	SCI-220	Biological Science - Ecology
III	SCI-320	Introductory Physical Science
	SCI-220	General Science - Traditional
IV	SCI-412	General Science - Traditional
	BIO-412	Biology - Traditional
	BIO-422*	Biology - General
	BIO-442*	Biology - Human
	CHEM-442*	Chemistry - Traditional
	CHEM-462*	Chemistry - ChemStudy Modified
	PHY-442*	Physics - Traditional
	PHY-432*	Physics - HPP
	PHY-452	Physics - PSSC
V	BIO-532	Biology - BSCS
	CHEM-562	Chemistry - ChemStudy Modified
	PHY-512	Physics - Traditional
	PHY-522	Physics - PSSC - 1 year
	PHY-522	Physics - PSSC

NOTE: * indicates Secondary V credits.

Information taken from System of Codification for Secondary Courses and Examinations 1979-1980. Direction de la mesure et de l'évaluation des apprentissages, Gouvernement du Québec, Ministère de l'Éducation, Direction générale du développement pédagogique.

Table 2 - Number of Students Registered to write June 1980 Examinations

Level	Description	Number of Students	Percentage
SECONDARY IV	BIO-412	3 265	27.3
	BIO-422	2 041	17.0
	CHEM-442	5 216	43.6
	CHEM-462	3 067	25.6
	PHY-432	411	3.4
	PHY-452	1 409	11.8
	ENG-422 COMP.	11 972	
SECONDARY V	BIO-532	790	7.3
	CHEM-562	2 751	25.4
	PHY-512	4 471	41.2
	PHY-522	299	2.8
	PHY-552	1 061	9.8
	ENG-522 COMP.	10 844	

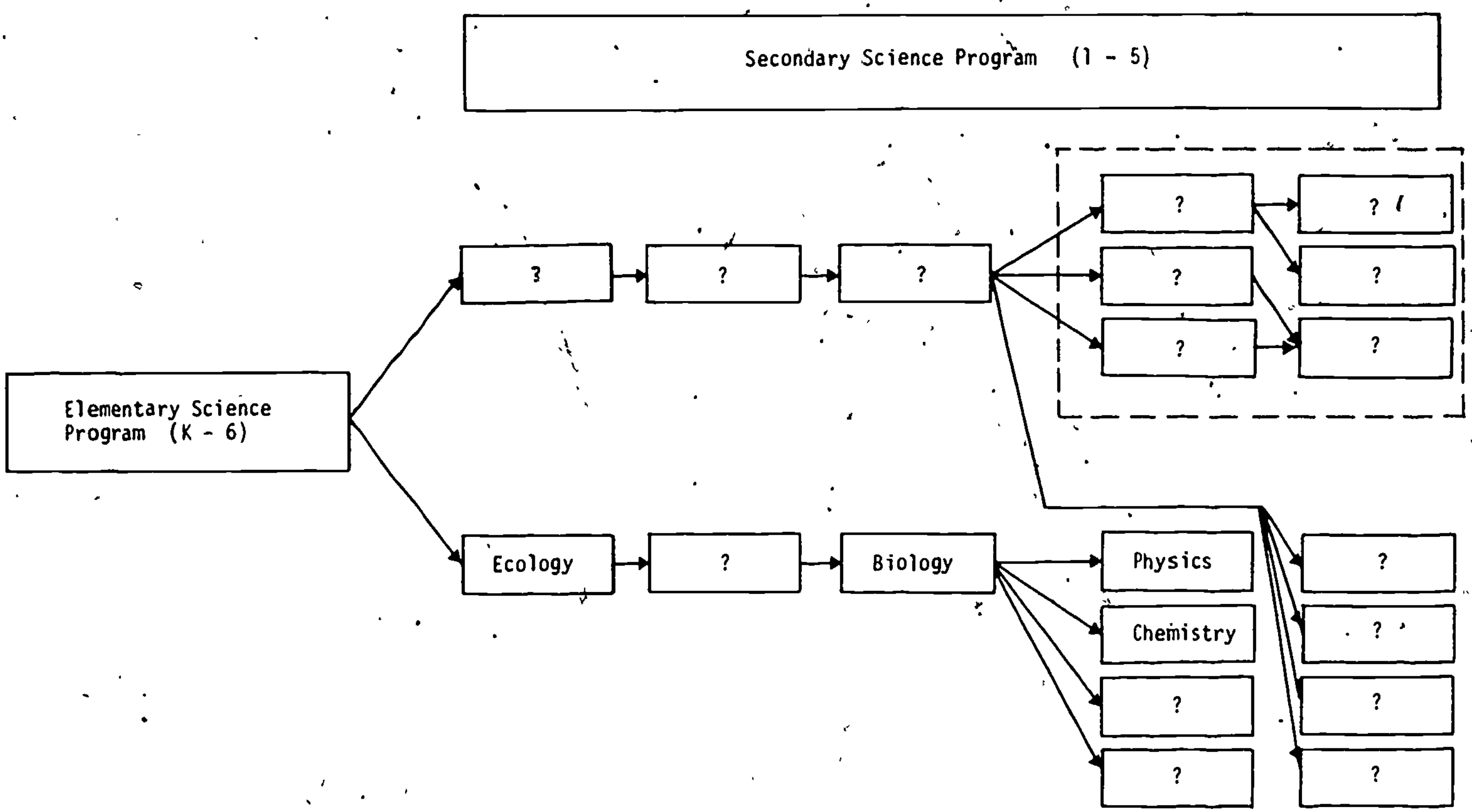
Note: Information taken from Ministère de l'Éducation, Direction de l'évaluation pédagogique. Résultats des examens de juin 1980 dans l'enseignement public.

Table 3 - Subjects and Time Allotments - Secondary School*

	Credits per Year				
	Sec. I	Sec. II	Sec. III	Sec. IV	Sec. V
Language of Instruction (English or French)	6	6	6	6	6
Mathematics	6	6	4	4	4
General Geography	4	-	-	-	-
Second Language (FSL or ESL)	4	4	4	4	4
Religious Education	2	2	2	2	2
Personal & Social Development	1	1	1	1	1
Physical Education	2	2	2	2	2
School & Vocational Information	1	1	1	1	1
Art	4	4	-	-	-
Ecology	4	-	-	-	-
General History	-	4	-	-	-
Family Economics	-	4	-	-	-
National Geography	-	-	4	-	-
Biology	-	-	4	-	-
Introduction to Technology	-	-	4	-	-
National History	-	-	-	4	-
Chemistry or Physics	-	-	-	4	-
Economic Education	-	-	-	-	4
Sub Total	34	34	32	28	24
Options	0 - 2	0 - 2	0 - 4	8	12
TOTAL	34-36	34-36	32-36	36	36

1 Credit - approximately 25 hours of activities
6 Credits - approximately 36 weeks @ 1500 minutes (5 periods per week of 50 minutes each). See details in Course Options Offered in Secondary School, attached.
Proposed date of implementation of the subjects and time allotments - July 1, 1986.
* From Proposed Régime Pédagogique, November 1980.

CHART 3: PROPOSED SEQUENCE OF SCIENCE COURSES
IN THE ENGLISH SECTOR FOR 1982 TO 1986.



Science Teaching:
An Answer or a Question?

Mr. Marcel Risi

Commercial Director
Centre de recherche industrielle du Québec

An article published recently in the magazine Commerce (Le Point, 1980) included a review of the changes that will occur during the 1980s:

- problems and unknowns will flourish;
- possibilities for change and progress will increase enormously;
- we must meet the challenge of change and adapt to new directions;
- markets will orient themselves around the needs of the end-user;
- the least competent will go under and competence will be increasingly tied to creativity;
- there will be an increasing need for original solutions and for innovations;
- consumption patterns will assume new orientations.

According to this review, the real problem of the 1980s will be change, or rather the necessity for change, even if on principle people prefer the status quo. Change cannot, however, be the result of a rational process; it requires creativity, which is dependent on knowledge, imagination and the environment. The essential role of education lies precisely in its ability to have a direct impact on the scope and orientation of knowledge as well as on the use and control of the imagination, so as to cultivate the ability of individuals and thus enable them to change their environment.

In a very fluid environment, education should provide the individual not only with information on what the world is, so that one can adapt to it, but also on what one is, so that one can adapt the environment to oneself. Bernard Shaw wrote, "The reasonable man adapts himself to the world. The unreasonable man tries to adapt the world to himself. In consequence progress depends on the man who is not reasonable." Paul Valéry had the same idea when he wrote: "For the profession of a philosopher, the essential thing is not to understand."

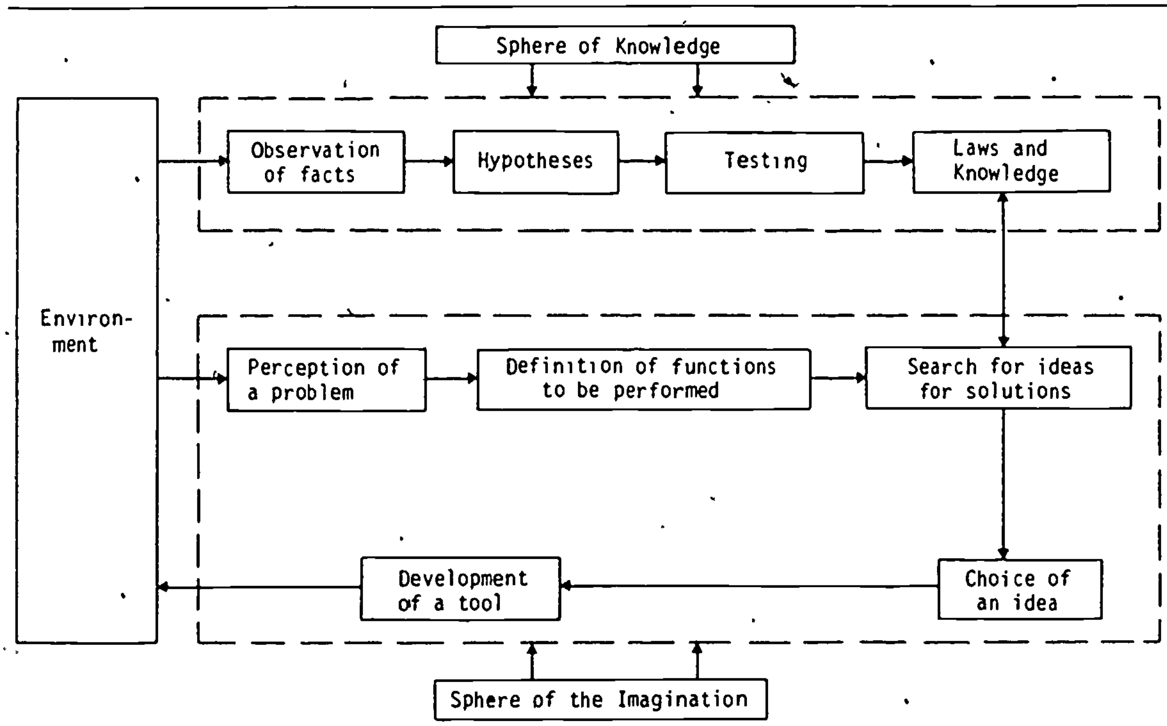
This paper is therefore an attempt to propose a number of points for reflection on the potential of science teaching from the point of view of the needs of industry.

Understanding and Shaping the Environment

The point of departure for my considerations is a concept so vast it has room for everyone: the concept is "my environment," or, "the world in which I live my daily life." "Environment" encompasses all aspects of a person's daily life, from the family, to the urban or national community, and corresponds to the world as perceived by sociologists, economists, ethical philosophers, technologists, biologists and so on.

The following chart demonstrates schematically the link between the various elements of two creative processes that can grow out of reflection upon and analysis of the environment.

The Elements of Creativity



The Human Legacy

There are those inquisitive minds that are regarded by some as peculiar. It is worth noting that these inquisitive minds have become increasingly rare, as a result of the conformist education of the past few decades, which discourages the average person from asking many questions. Inquisitive minds distance themselves from the usual considerations and ask themselves why things are as they are and what purpose they serve, until finally they see "with new eyes" facts that no one has noticed before.

Once they have perceived the facts, they search for an explanation to serve as the basis of a hypothesis. Not until the Renaissance did people learn to construct systems to verify their hypotheses with the help of a model of the universe reduced to principal causes and effects. Bacon developed the principles of the experimental method subsequently perfected by Mill and Bernard. It then became possible to verify a hypothesis experimentally and to derive from it a scientific law. The sum of all the scientific laws today constitutes our intellectual legacy.

In the true Cartesian tradition, we are reluctant to regard as scientific anything which is not measurable: as a result, we recognize as scientific laws only those which are capable of being expressed in terms of a mathematical model. It is easy for us to proceed by paradigm, so when we have learned to conjugate the verb "aimer," we assume we know the conjugation of all verbs that end in "-er." Similarly, once we have learned Newton's first law, we assume we can calculate the speed at which an object in a free fall from a given height will hit the ground. However, when we realize that the law of an object in a free fall applies equally to Newton's apple and to a worker falling from a scaffold, we are forced to admit that physics can no longer be considered the prototypical science and mathematics the pure wellspring of all the sciences. The experimental method as part of the circle of knowledge enables us to understand but not to act.

However potent our thoughts, they have no effect on the environment in which we live: the world is never changed by the discovery of a scientific law.

The Need for Solutions

On the contrary, an understanding of how the world is changed or how it is possible to change the world requires the other creative approach, a practical or functional discovery. This creative process also starts from the everyday environment, but in this case the environment is seen through the eyes of revolutionaries or protesters. From this viewpoint, it quickly becomes apparent that things do not work, or are no longer working in the world, that there are problems, hindrances, disadvantages, calamities: people are hungry, at war, sick, hot, cold and so on. This viewpoint can set in motion effective processes of change in the world because problems are perceived as obstacles to the attainment of an objective, and the elimination of these obstacles will make it possible to change the world.

As long as protest is not gratuitous, it leads to consideration of a possible solution to the problem, in other words, to the precise definition of a function to be performed: something that will feed the hungry, something that will bring peace, something that will heal the sick, warm the freezing, refresh and so on. Once a proper definition has been found, the search can begin for the ideas for solutions, which leads to a search through the compendium of scientific laws and knowledge in an attempt to validate the proposed ideas. At this point there are two alternatives: either we find what we need in some knowledge we already possess, which needs only to be applied, or it is necessary to cover the entire circle of the experimental method again in order to prove the idea for a solution. We must choose one of the ideas for solutions that we find, and the choice is made on the basis of an evaluation and classification of all the ideas. The final stage is the development of the tool, which by definition is an instrument, either simple or complex, created for human use in solving problems.

Sometimes it can be manufactured directly from raw materials, and sometimes it is a second-degree tool produced with the help of existing tools. It is worth noting that the tool is an innovation in the sense that, although it uses existing elements, it does so in an original way. In the broader sense of the term, the tool is not necessarily a tangible instrument: it may be a procedure, a constitution, a prejudice, a habit, a law, mode of behaviour and so forth.

The tool thus created is eventually introduced into the environment, which it sometimes changes and often makes more complex. The new and complicated tools designed to solve problems make the world more and more disconcerting, to the point where even though people live better today than in the past, they nevertheless do so with greater difficulty and in an increasingly artificial world. Two prime examples of this trend are the automobile and the urban environment.

The Industrial Process

The industrial entrepreneur rarely uses the path of knowledge. His or her existence and survival are intimately linked to the solution of problems, both within a company and because of the purpose of the company: the product must fill a need, it must be the solution to a problem. Business people will not find a way to prevent falls from scaffolds by contemplating Newton's first law; they will do so by defining the problems that must be surmounted to achieve safety in the workplace, thus began the imaginative process leading to the development of the tool.

Despite their level of knowledge and education, however, people retain the power to find solutions based on knowledge that they do not possess. The caveman who fashioned the first stone axe was aware neither of the principle of the lever nor of the law of inertia nor the law of pressure. Closer to our own day, Pasteur could explain the properties of his rabies vaccine only in terms of the production of antibodies. Sometimes humans extend their genius to the point of developing, on the basis of a scientific law, a tool which will be the solution to a hitherto unknown economic problem. This was the case with the photocopier, which applies electrostatics and which was developed long before the need for it was felt.

Science Teaching

If we accept the premise that the next few decades will require solutions to increasingly complex problems and that creativity grows from knowledge, imagination and the environment, it becomes apparent that science teaching should abandon the process of the experimental and scientific method, creative though it is, because it is lamentably conducive to a false sense of security. While there is still value in providing the student with a solid background knowledge of science, it is even more important to help him or her perceive the evolving environment in a realistic way and to use creative capacities to define problems rather than to find solutions. We need to create a teaching method that will provide the mind with no answers, no safety net, but with a question through which the anguish of change is visible, as Claudel put it: "I am not an answer, but a question in reply to your question."

While it is relatively easy to define the objectives, the problems that must be resolved in order to attain them are complex and linked to behaviour patterns. The EVALENSCI project concluded that the new methods of the 1960s had been a total failure and indicated one of the possible causes: "There is little point in introducing a new program based on different attitudes and objectives if the teacher involved in the program still retains the old mentality" (Québec Science, December 1976). Souque and Désautels (Québec Science, September 1979) expressed the reality of the situation when they said:

> "Fortunately for the teachers, students are sufficiently docile that they absorb certain scientific explanations, trot them out in examinations and subsequently let them fade away. Because the new concepts that have been introduced have obviously not brought about any radical changes in the structure or personal framework

of our knowledge, they appear in the mind only in the form of impressions which ultimately evaporate."

The elements of a solution are perhaps to be found in their proposals concerning a real "cultural transformation." This seems a viable choice to me; it fits well into the environment of the "third wave" of the human revolution defined by Toffler as "the transformation of the minds" and by Teilhard de Chardin as "the psychological revolution." People will no longer accept that the purpose of knowledge is to increase power or possessions; they will want to contribute to improving the environment, the conditions of existence and work so that they can "be more." Science teaching cannot ignore these profound changes: it must stop showing how the individual can adapt to the environment and show how the environment, "the world in which we live," can be altered by developing a creativity which "searches for" the problems rather than the solutions.

II. FUTURE DIRECTIONS FOR SCIENCE TEACHING IN QUÉBEC

What Sort of Scientific Education
For What Sort of Society?

Dr. Jacques Désautels

Faculty of Education
Université Laval

To question the future of science teaching in Québec is at the same time to question the future of our society as a whole, for the two are inextricably linked. Asking the question in the right way, in my opinion, sheds light on this link and that is why I have entitled my paper "What sort of scientific education for what sort of society?," a reflection of the order of priority of the two parts of the question.

Even put this way, however, the question remains far too enormous and complex for a cursory examination. I shall therefore limit my comments to the teaching of science at the secondary level, in particular because it is at this level in the educational system that the future of scientific culture in our society is being decided. The vast majority of our fellow citizens in fact have no further contact with science teaching beyond this level of schooling. But can we talk seriously of the future before we have reviewed the past? What role has science teaching* played in our society since the early 60s?

Retrospective

It is clearly impossible to disassociate this role of science teaching from the more general one of the secondary school. Despite the good intentions of the authors of the Parent Report, the secondary school system has not succeeded in creating equality of opportunity in education.[1] Through its educational system, its method of operation and its hidden curriculum, the school reproduces "social classes and the social division of labour." All in all, the secondary school has the role of shaping the citizens of tomorrow, citizens adapted to an industrialized, capitalist, and increasingly technological society. Under these circumstances, it is not desirable that the majority of citizens should acquire the knowledge and capacity necessary for a critical

* In the text, the term "science teaching" refers to the secondary level.

1. Mireille Lévesque, L'égalité des chances en éducation, Ministère de l'Éducation du Québec, Conseil supérieur de l'Éducation, 1979.

perspective on social phenomena, particularly with regard to the relationship between science and society. It is against this background that we must examine the role that has been assigned to and played by science teaching.

An analysis of the educational programs and practices shows that science teaching has adapted perfectly to the school's requirements. By perpetuating overloaded curricula for years, often poorly suited to the intellectual development of the majority of students, the system has guaranteed that only a minority will eventually have access to scientific careers. By arranging curriculum content strictly according to logic and discipline, with no reference whatever to the history of science, apart from parenthetical anecdotes, it ensures that students do not absorb a critical view of knowledge. By divorcing curriculum content from everyday or cultural reality, the knowledge acquired is rendered useless for the individual in his or her daily actions. By disassociating science and technology, the framework is already prepared for the division of labour. By carefully avoiding the integration of the social problems related to scientific and technical development, generations of young people are prepared for a passive, naive acceptance of what passes for progress. One can perhaps summarize this by saying that science teaching has fulfilled the role assigned to it of preparing an elite according to the requirements of the university to the detriment of acquiring a true scientific culture by the majority. It is hardly necessary to add that this constitutes a lamentable failure in a society where daily life is shaped and stamped by science and technology. In the words of Arthur Koestler, modern man is an "urbanized barbarian," living as a stranger in his own environment.2

In fact, this is just one further failure to lay at the door of educational reform, and a similar diagnosis could in all probability be

2. Arthur Koestler, Le cri d'Archimède, Calmann-Levy, 1965.

drawn up for all subjects. This particular failure is merely one more symptom indicating that it is the school system that is at fault, and, by extension, the society of which it is a faithful reflection. The society at fault is one dominated by large, technocracy-based financial trusts, founded on profit and production for their own sakes and which reduces human beings to the status of passive consumers of material and nonmaterial goods. Hence the question: what sort of scientific education for what sort of society?

Some Indicators of the Future

What sort of society is it really? What sort of society will we have if present socioeconomic trends are maintained? According to a recent study by the Stanford Research Institute[3], we can anticipate that the imbalances characteristic of our society will be exacerbated. The following are some examples of these:

- relative exhaustion of energy and mineral resources;
- exhaustion of arable land and growth of deserts;
- threat of destabilization of the major ecological cycles;
- growing gulf between the privileged and the poor;
- increase in the so-called ills of civilization;
- threat of world wars and so on.

All this will be accompanied by an increasing centralization of political and economic power. In what way is this a society which we will fashion collectively as a reflection of what we are?

In one scenario, we abandon our normal right to direct the development of society and place it in the hands of a technocracy which will define our needs for us. In another, which some people will say is improbable, we embark upon a path of creativity and social renewal. In any event, the former option would require only minor alterations in

3. Stanford Research Institute, Two Views of the Future: Scenarios, Methodology, Parameters, Menlo Park, California.

current trends in science teaching. The latter, on the contrary, would necessitate a major reorientation.

A Sketch of Society

Imagining a better world turns out to be more difficult and more absorbing than imagining the "best of all possible worlds" towards which we are drifting gently. As the economists well know, the complexity of our societies is such that any prediction concerning their future is somewhat dubious. However, in the absence of the long view, all action in the short term is blind and one cannot see the wood for the trees. It is therefore necessary to sketch out, subject to modifications along the way, certain characteristics of a better society. This is less a matter of developing a new utopia than of establishing a few reference points for action. This better society could be:

1. More decentralized: The central core of this vision is a community on a human scale. Without becoming an autarchy, the community would possess those political and economic powers enabling it to determine the course of its own development. It would tend towards a more direct form of democracy; it would also tend to control the means of production on its own territory, leaving open the possibility of cooperation with other communities in more centralized forms of production requiring the deployment of larger resources. Within large cities this concept of a decentralized community could be on a neighbourhood scale.

2. More ecological: This is not a question of advocating a naive form of environmentalism according to which Nature is a source of wisdom and ecology itself becomes a new ideology, but rather of developing an ecological conscience in the sense used by Edgar Morin when he writes: "The ecological conscience is not only an awareness of the degradation of nature: it is an awareness, under the influence of the science of ecology, of the essential character of our relationship to living nature. It springs from the dual concept that society is totally dependent on the natural ecosystem, which in turn is profoundly affected and degraded by and for our social processes... . From the point at which the ecological conscience deepens into an 'eco-anthropo-social conscience,' it also develops into a political conscience in the awareness

that the disturbance of the organization of nature poses the problem of the organization of society."[4]

This conscience has already given rise to many individual and group-actions in our society and will eventually guide the community towards more gentle forms of technology, to the use of diversified, nonpolluting sources of energy, to the promotion of conservation and recycling, and the integration of the community into the natural landscape within which it evolves.

3. Technologically more sophisticated: This would involve a reversal of the present situation. Instead of society being determined by technology, this new context will produce a technology that is socially determined, in other words, adapted to needs defined by society as a whole.

   It is moreover apparent that this community will not be able to dispense with the appropriate technological infrastructure if it is to maintain either its material existence or its spiritual development. It will draw its sustenance in large measure from the quality of its relationship with the rest of the world. In this context, however, there is no doubt that the question is less one of determining what is technically feasible than of knowing how technology can be made to serve humanity.

Realistically, however, we must admit this will not come about overnight; the important thing is that this sketch should serve as a catalyst in the evolution of society. It does not have to be regarded as an ideal to be attained, but rather as an invitation to change course towards a horizon which is subject to constant redefinition. It will perhaps be easier to perceive this change if we review the elements of the following table, which shows the evolution of some of the values and attitudes associated with this vision of society.

This trend implies a change in mentality which will doubtless take a long time to reach fruition.

4. Edgar Morin, La Méthode, vol. 2. La vie de la vie, Éditions du Seuil, 1980, pp. 91-92.

Table I

From	To
individualism	self-sufficiency
competition, domination	sharing, cooperation, participation
aggression, mistrust	readiness to experiment
conformity, adaptation	self-criticism, creativity
materialism, consumption respect for hierarchical authority	austerity, frugality constant questioning
exploitation and mastery of nature	cooperation with and integration into nature
linear thought	complex thought
mechanistic vision	global, holistic vision

A Blueprint for Science Teaching

The orientation sketched out above could be associated with a new blueprint for science teaching, which would deal less with specific content than general orientation and educational principles. Here as elsewhere, a far-reaching degee of decentralization is the only way in which the peculiar and sometimes unique requirements of the regions and the communities can be reconciled.

The Orientation

In that decentralization is not synonymous with either isolation or closed-mindedness with regard to innovation, the following broad orientation would be shared:

1. A desire to promote a critical view of society based on the study of the macroproblems confronting our civilization;

2. A desire to demystify science, technology and their heroes by integrating the purpose, history, social role and critical self-analysis of science into the teaching of the subject;

3. A favourable attitude towards individual and collective development of knowledge and capabilities to enable society to master technological development and ensure the balance of the natural and social environment;

4. A favourable attitude towards the integration of the various disciplines and the promotion of a global view of the world, society and the individual;

5. A favourable attitude towards the absorption of work methods appropriate to the sciences;

6. A favourable attitude towards the creation of an educational network in the community.

A few comments on these proposals are obviously required. It will be noted,

- that these proposals integrate science and technology into science teaching;
- that the history of science is integrated into the teaching process; in this context we should not confuse the romanticization of science and the history of science. The romanticization of science, like nationalist history, can generate more confusion than clarity;
- that the educational blueprint goes beyond the strict confines of the school and becomes part of the community.

Educational Principles

Traditional educational principles are obviously irreconcilable with the general orientation of these proposals. An educational philosophy adapted to this sort of blueprint would probably include the following characteristics, independent of the specific strategies developed in each field. It would be:

- an education to develop awareness, because it is built around problems, the roots of which are social;

- a significant education, because it is based from the outset on problems significant for the individual and the group;
- a synergetic education, because it promotes work methods which encourage cooperation between individuals;
- an autodidactic education, because it promotes the development of the individual's intellectual and emotional self-sufficiency;
- a creative education, because it is not centred exclusively on the transmission of knowledge but rather encourages the exploration of new problems while taking into account the students' intellectual development;
- an interdisciplinary education, because it is centred around problems that encourage explanations in light of several disciplines;
- an integrated education, because it encourages the development of the capacity of individuals and groups to affect their environment;
- a community education, because it encourages the creation of an educational network within the community.

All is possible if ...

Such a change, considered in the light of current trends in science teaching at the secondary level, is so radical that it can come about only if certain conditions are fulfilled. Some of these are:

- an awareness on the part of teachers of the social function exercised by science teaching over the past fifteen years and their roles as channels for the transmission of the dominant values which they themselves have played in this context;
- a psychoanalysis of the feeling of impotence that overcomes us when confronted with the possibility of changing the course of society's evolution;
- a desire on the part of teachers to embrace collective rather than individualistic action. Interesting educational projects are too often appropriated by the administrators because of a lack of cooperation between teachers;

- a desire on the part of science teachers to cooperate with other teachers and other members of the community in the creation of educational projects.

Conclusion

That, in a nutshell, is my view of the future of science teaching at the secondary level. In closing, I would like to remind you that teaching implies a commitment and that it is our responsibility to clarify the direction of that commitment. For the past few years we have unfortunately sought refuge in an attitude of pseudoneutrality as far as our work is concerned, and have all too often been content to act like "officials" in education, to be merely cogs in a machine rolling in a direction over which we have no control at all.

It is, however, precisely the problem of direction that is raised when we discuss the future of science teaching, and the discussions that will take place in the course of this symposium will be fruitful only if their framework is sufficiently broad to enable us to answer the question: What sort of scientific education for what sort of society? I think we can assume that this debate will be stimulating for all of us and will enable us to rediscover that degree of enthusiasm without which education becomes merely a question of a teaching assignment.

Dr. Graeme Welch
John Abbott College

In any discussion of future directions for science education it is easy to propose sweeping changes in curriculum and methodology. A more difficult task is to make an honest and objective analysis of the fundamental problems that exist in present day science education and to form a realistic assessment of how they may be coped with in the next few decades. Such issues as the unionization of teachers, and the concomitant decline in their professional status are difficult to face, but are as important as any alteration to the syllabus or the introduction of new techniques. In the following comments I have been deliberately provocative in attempting to expose some of these issues and to emphasize that the future directions of science education must be planned with the recognition that major changes will be needed if the quality of science education is even to be maintained, let alone improved.

Textbooks reflect the state of education clearly, and the changes in some of the more popular and successful undergraduate textbooks are very revealing. For example, one of the most frequently used textbooks for first-year level chemistry has undergone numerous revisions and has been re-edited five times over the last fifteen years. A comparison of the 1966 edition with the latest (1981), shows that many topics have undergone a substantial dimunition in complexity. For example, the chemical bond is now discussed in relatively qualitative terms and the full discussion of orbital energy correlations has been omitted; the Clausius Clapeyron equation (which involved logarithms) has been dropped completely, the full-scale treatment of reaction kinetics (which assumed a knowledge of calculus) has been reduced to empirical equations and the first law of thermodynamics has been relegated to the "blue pages" as optional reading because it involves abstract concepts like "work"!

Most teachers would agree these modifications are necessary because the students are less well prepared than they used to be. But it is useful to examine this phenomenon from a somewhat different perspective; from the viewpoint of an historian of science education shuffling through dusty tomes in some obscure library in the year 2084. Our historian might come to a completely different opinion; the last three decades of the twentieth century were strange indeed. The students appear to be just as resourceful, just as dynamic, just as intelligent, just as exciting and vital as ever - the evidence for this is clear in their music, in their political activities, in their athletics, in their social history, etc...but their teachers, particularly their science teachers changed in a strange way. From about 1960 onward they went into an intellectual decline, they no longer knew how to use logarithms and the calculus, they appeared unable to grasp abstract concepts, and seemed to forget the importance of the fundamental laws; why, some of them even told students it wasn't really necessary to know about the first law of thermodynamics. They became very vague about explaining who did what and when; perhaps they lost all sense of cultural perspective or couldn't cope with names and dates.

Science educators may complain and argue all they want about how the students are ill-prepared, unable to cope, not motivated, uninterested, etc., but the unpleasant truth must be faced. Instead of actively recognizing the changes in the student population and adapting to them realistically and intelligently, the professional standards of the teaching profession are dropping at the same rate that the reading, writing, and arithmetic skills are apparently declining in their students.

The cure for such a state of affairs is very complex. It is not simply a matter of raising standards. An attempt to raise the standards to even the same level as 1966 would be catastrophic. What is clear, however, is that the future of science education, and of science itself, depends upon recognizing that there are still many students who have the innate ability to work at a higher level and that there must be policies that allow teachers to cater to these students.

At this point, it is worth examining the situation of the present day science teacher. In Québec there is somewhat of a paradox. These teachers, especially those like the author, with PhDs, are close to being the best paid in the world; they also have some of the best working conditions and the lightest workloads. Once ensconced on the seniority list they have a secure position for life, and a wonderful pension after that; surely this should be a place where educational opportunities abound. Wondrous things should come from such a system! But no, instead, teachers seem to be becoming increasingly apathetic, they have little motivation to improve (unless it be to obtain a PhD so they can move up the salary scale). There is little incentive for innovation and no reward at all for dedication, even to existing methods. Add to this glaring anomalies, for which there are no attempts being made to find solutions. The best young, energetic teachers are being fired, while no effort whatever is being made (due to decreased enrolment) to encourage young people to enter the profession in any significant numbers: Meanwhile, totally incompetent teachers are completely protected by an absurd web of complex contract regulations and union rules.

The unionization of teachers may very well have brought the profession out of the nineteenth century, but is very likely to strangle the profession completely before the twenty-first is even reached. No profession can survive without the constant infusion of new ideas, energy and people, and this should be a matter of vital concern for the next decade. It is not surprising that teachers find it easier to drop difficult topics from the curriculum than to maintain reasonable standards. However, before it may seem as if the educational administration and government departments are completely blameless, another aspect which is kept well disguised must be considered. If both universities and colleges are willing to concede that twenty-five per cent of their students are functionally illiterate, they are nevertheless far less willing to consider simply not accepting these students. The fact is, the curriculum policy of these schools is often based more on the necessity of obtaining funding (which is dependent on the number of students) than on the real academic ability of the students that are admitted, or the needs of the society into which these students will graduate.

Apart from influences such as teachers' job security and administrative funding requirements, the present science curriculum is based on conflicting contractions. At a time when science-based careers require an ever increasing degree of specialization, the science curriculum is vaingloriously upholding the principle of growing generalization. The difficulty is that a balance must be found between the needs of technical specialization and the exponential increase in scientific information. One thing is clear; continued dilution of the syllabus is not the answer. Some previous attempts, notably ChemStudy, and PSSC (Physical Science Study Committee) have been based on abstracting fundamental (but generally abstract) theory but have been unsuccessful because these theories become meaningless to students when divorced from concrete observations and experiments. The problem of designing a science curriculum for the future needs of scientists is perhaps best illustrated with an example. In the early 1960s, (at which time I was a student at the University of Toronto), there was much talk of absolutely necessary complements to the science curriculum. For example, it was suggested that no one could successfully cope with modern science without a detailed knowledge of such topics as electronics, statistics and how to write a computer program. As a result I dutifully enrolled in a FORTRAN programing course (and I must admit it has proved useful). At the same time, however, university regulation prohibited the use of electronic calculators in an examination. This was absurd enough, but the ridiculous irony is that I can now buy an electronic calculator that will achieve, with a few key strokes, all the routines that I learned to write in my FORTRAN course!

I hope you will not interpret this as meaning that science students need to know about computers, but what it does mean is only a limited number need to know how to write FORTRAN programs and even fewer students need to know how to design computers. Just because computers have become an integral part of science does not mean every scientist must have a FORTRAN course. Nowadays a modern computer is so complex that any scientist who needs computer routines will ask a professional programer to write them. The limited knowledge to be gained from an introductory FORTRAN course is completely useless. If we are going to teach computers then the emphasis should be on training experts who are so good that their products are simple to use from an instructional manual. This means, incidentally, that such people must be more than computer programers, they must be highly literate and able to communicate their ideas and instructions effectively. Instead, the present system is producing a race of semi-illiterate scientists who have vague ideas of how a computer works, a limited ability to write a computer program, (at a level well below that which would be useful to them) but who are incapable of reading an instruction manual! This would be a more severe problem were it not for the fact that many computer manuals are so poorly written they are completely unreadable regardless of the literacy of the user. The lesson to be learned from this is that the curriculum must be based on fundamental skills and knowledge to ensure that the graduating student has the level of scientific literacy to be able to adapt to the progress of science and the expansion of knowledge.

While science educators have debated the proper direction for the curriculum, the student population has undergone substantial changes. My own experience illustrates this well. I grew up in a small provincial town in New Zealand. In my first year at high school (Grade 8) there were about 400 students, but because it was a rural area, by Grade 12 most of these had departed to jobs on farms etc. In fact there were only 18 survivors in the last year. Apparently the rest were able to cope with life without even taking chemistry or physics. (At least two of them I know became millionaire construction magnates). The point of this story is that there was a very good reason for teaching the specialized science courses (including the differential calculus, logarithms, and the first law of thermodynamics) because the only students left were in a good position to take advantage of them.

A much greater proportion of students are now staying to complete their secondary education and proceed to college. The only concession science educators have made to this fact is to dilute the content of courses and to prepare an increasing number of remedial (or make-up) courses. The result: at the college level there are large numbers of students who, even assuming something penetrates after repeating the course three times, have little chance of ever using any of the knowledge and skills they may have learned. What is worse is that at John Abbott College, for example, 633 of the 688 science students think they are taking these courses in order to be admitted to medical school (the remainder intend to be dentists). Science educators must remove the blinkers and realize that students are not necessarily ill-prepared but that there are too many students taking the wrong courses for the wrong reasons.

The consequences of this are very important to the future of science and, in my experience, they have not been well recognized. First, a large number of students at the high school level are being taught (exposed to, at least) absurdly high-level, abstract scientific concepts, when they would be better occupied in reinforcing the fundamental skills such as reading and writing. Secondly, the students who could take advantage of specialized courses in the scientific disciplines are being denied the opportunity. Five per cent of the adolescent population were capable of not only understanding, but of being fascinated by differential calculus at age seventeen, 20 years ago, and there is no reason to assume this group does not still exist. No one benefits from the present situation. Too many students are being encouraged to study abstract science theory at a level that is too advanced and that only serves to prejudice the proper development of more fundamental cognitive and literary skills. The more able students are not receiving encouragement and opportunity to develop a proper understanding of science.

Meanwhile, the response of science educators to these pressures has been shameful. Using the excuse of an over-burdened curriculum, the science teacher has come to believe there is no time, no space and that he or she is not responsible for the reinforcement of basic skills. I believe that students leave elementary school as well prepared as ever, the problem is that these skills are not reinforced at the secondary level and hardly at all in college. For example, at John Abott College, students are no longer required to write laboratory reports in biology courses - they "write" multiple-choice tests instead. A science teacher has as much responsibility as a language teacher to ensure students use their language skills properly. A student must see the advantages that language can provide, and come to understand the importance of communicating ideas with clarity and precision. The problem is also cumulative - as more difficult concepts are dropped from the syllabus (logarithms, calculus etc.,) the program of studies becomes larger, and more generalized, but fundamental scientific knowledge is forgotten. By the time students are exposed to logarithms for example, it is too late, the proper scientific context is missing. Finally, science teachers appear to be party to the insidious practice of examining their students at a level far below that which appears in the syllabus. Even a cursory comparison of a provincial examination with the syllabus makes it evident few of the real ideas, concepts or skills are being tested. The student is examined at a totally superficial level; he or she is no longer required to demonstrate any understanding or knowledge, but only the recognition of incidental information presented in a multiple-choice examination.

In conclusion, science educators have not had the courage to make the necessary changes to the curriculum but instead have tampered with the methodology in such a way as to provide no advantages to any student - whatever the level. Teachers, too busy trying to find superficial ways of evaluation that will disguise the fact that students do not understand the topics, have ceased to exercise their fundamental responsibility of reinforcing linguistic, mathematical and cognitive skills. The more complex topics are being dropped from the curriculum because the less able students cannot cope with them, but in doing this the better students are being denied the opportunity of practicing, reinforcing, and recognizing their true value of essential skills in practical situations.

In the next few decades, society will require scientists who are better educated than ever. This aim will not be achieved by teaching everybody a little about science, especially if this is done at the expense of basic knowledge and skills. The science curriculum must be completely redesigned so that those students who are capable of the intellectual skills required may make full use of their own abilities. The problem of science education is not that the students are ill-prepared. It is that the science educators are not prepared to recognize that students now are not the same as those of 30 years ago. Too little is being taught about too much to too many. Nobody gains.

Dr. Germain Gauthier

Vice-President, Education and Research
Université du Québec

We have been invited to reflect together on the future of science teaching in Québec. I have had no personal experience with futurology, apart from deriving some spontaneous enjoyment from economic analyses and from advancing possible hypotheses concerning future developments. If I therefore use terminology borrowed from futurology, it is quite by accident and does not in any way compromise the seriousness of this new science.

I shall attempt, within the framework of the decade from roughly 1980-1990 and on the basis of marked trends that are already discernible, to identify some important characteristics of the social and educational environment in Québec; and to outline certain desirable approaches. I would like to point out at the outset that I shall view the question of science teaching within the context of the privileged relationship that exists between a teacher and a student or a group of students, especially at the secondary or college level; this is an environment which is itself framed by the broader context of society as a whole and therefore includes the family and the primary and university levels of education, among others.

The privileged relationship between teacher and student cannot help but give rise to considerations relating to the chain of transmission of knowledge, namely, the quality of the source, the nature of the channels of transmission and the quality of the student-receiver, as well as the phenomena of essential dynamic reactions.

The first characteristic of the social and educational environment that I believe will have an influence on the future of science teaching in Québec over the course of the next decade is declining enrolment, which will result in a commensurate end to growth and decline in the number of teachers. This phenomenon was defined for the universities by the Science Council of Canada, and it is no less applicable and important for the secondary school and college levels.

We have, for example, just determined that the entire secondary school system in Québec will require, over the next six years, an annual maximum of 150 young university graduates to supply a pool of 32 000 teachers. This is between zero and three graduates per scientific discipline and university training program. Furthermore, we also know that at the college level there are at present more than 500 surplus teachers who have job security but no teaching responsibilities.

These few figures point inexorably towards an almost zero renewal of the faculty, and to their increasing age. This development has important consequences for the effort required to provide students with initial or advanced training, and oblige us to review in depth the type of basic education that should be offered to students to equip them with the degree of diversity required in the face of an uncertain job market. In any event, they oblige us to revise a teacher training policy that has taken this important factor insufficiently into account.

The second characteristic of the social and educational environment that I would like to mention, or rather recall, is that school and college are no longer the only environments where scientific information is imparted, and in the next few years, with the anticipated rapid advances in communications, science and technology will be within the range of every citizen's home.

At the same time as we notice a degree of disillusionment with the scientific disciplines at the secondary and college levels, as well as with scientific programs at university level, it is worth pointing out that there are in Québec, on the periphery of the school system, 95 vigorous young naturalists' clubs, one youth science council in the process of transformation or redefinition, and La fédération québecoise du loisir scientifique, with 250 affiliated local chapters operating in a dozen scientific disciplines. These associations have a total membership of 60 000, almost double the figure of ten years ago, reflecting a shared interest at the grass roots that is encouraged by a humble

$300 000 donation from the Government of Québec: they provide a striking example of Toffler's forecasts in Future Shock and The Third Wave.

There is a considerable discrepancy between school and college, where science is a "poor seller," and real life circumstances, where, in response to the demand of audiences of all ages, whose leisure time it increasingly monopolizes, science becomes more and more fascinating to the media. Have school and college lost before this race has even begun? Are they still trying to do what other institutions can do better than they, and thereby proving Ivan Illich right? Are school and college trying to redefine their own particular, fundamental role - that of institutions for training, in this case for scientific training - for awakening interest, for synthesizing and integrating; taking advantage of their role as unique institutions whose characters have from this perspective much in common with that of the family.

These questions obviously bear on the curricula determined by the Department of Education; they are naturally relevant to the question of teacher training programs; they are fundamental questions for every teacher who, in front of a group of high school or college students, attempts to meet their expectations and needs for training and knowledge.

I would like to add that there is, in my view, a third characteristic or tendency in the scientific community today which has a definite impact on science teaching. Not only is science progressing very rapidly, or exponentially, as some maintain, but science and technology, which were once separate and distinct, have moved together to a point where in some areas they are synonymous. As evidence of this trend I would cite the ever-shorter intervals between scientific discoveries and their technological application, as well as the way in which, in our universities, applied projects are increasingly intertwined with basic research, and the increasing amount of basic research which is being conducted in the major industrial laboratories. I would also cite as evidence recent work with transistors, lasers and biotechnology, where the phenomena in question bear witness both to the intimacy of nature and to the infinitely small.

Hence, in my view, questions need to be raised in science teaching about the excessive separation between theory and its application, between pure and applied science. There is also, I believe, the need to reopen the debate between the inductive approach and the deductive approach in science teaching, to review the objective and purpose of science teaching here at the secondary and college levels in light of the context, constraints and marked tendencies that we are able to identify.

Twenty years ago, two colleagues and I collaborated on the publication of a physics textbook that was used in Québec. I can remember the consternation of the publisher when, at the public launching of the book, I declared before a hundred or so people that I hoped that a competitive text would appear within five years and that I would be disappointed if our textbook were still in use in 10 years' time. I can admit today I was disappointed; in my view, both science and society deserved a better fate.

In all seriousness, I believe that scientists in Québec have a social responsibility which they cannot ignore. They must not only sound cries of alarm, but they also have a duty to hurl themselves into the mêlée and to rethink, for themselves and for their peers, the very foundations of their work and their impact as scientists, as teachers and as the trainers of teachers.

There are three possible consequences for action on our part as I see it, taken from the three characteristics I have described.

First, the teachers at the secondary and college levels for the next decade are already in place to a large extent. This fact should influence teacher training programs, especially advanced training programs. It seems to me that the Department of Education, the school boards and the universities should direct their concerns towards a type of teacher training which will be less compartmentalized and more open to a variety of work functions, as well as to an ongoing upgrading of teachers, either on an individual level or organized by general agreement among all those concerned. There is a consensus in most professions, such as health sciences, engineering, architecture, even in administration, that professionals must be careful to maintain a constant level of competence, in view of new developments in their profession, in order to keep up the quality of service to the public and, it must be admitted, to maintain the level of their personal income.

The need for this kind of upgrading is of course something of a departure from the concept of a personal need; it is echoed in appropriate work conditions as well as in the effective support of employers and the universities.

Secondly, it seems to me we must return to the essential purpose of the school or college as an institution and to a redefinition of its role. This is, first of all, one of training. I believe it is a question of enabling the student to integrate information about science and technology into a personal scale of values, or, as has been said, to bring science closer to students by enabling them to perceive science and technology as tools at their disposal, and making them aware of their significance and scope.

Thirdly, there is an increasing interaction between science and technology. I believe students are themselves aware of this and that they make the connection, even when their education separates the two. Would it really be an affront to science to define and enlarge upon this on the basis of experience and knowledge? It is less a matter here of arousing interest among students in scientific careers than of bringing all students to a point where they draw the connection between science and everyday life.

I remember with a great deal of pleasure the discussions I had in class, at a time when students did not wear beards, by asking them to calculate the amount of time necessary to amortize the cost of an electric shaver, bearing in mind the consumption of electricity, in comparison with the purchase price of a straight razor and the consumption of razor blades. Obviously, the answers could easily be doubled, depending on whether the razor blade was changed every day or every other day. I was even accused of not presenting a real physics problem. After some discussion, however, I am sure the students had a better idea of the wattage of an electric shaver and the cost of a kilowatt hour (which they must have been able to verify on their Hydro-Québec bill), and that they had a better idea of a postulate, a hypothesis, an order of magnitude and of a physical law.

III. ADDRESS BY MR. PIERRE SORMANY

Mr. Pierre Sormany

President,
Association des communicateurs scientifiques du Québec

For almost ten years my profession has been that of a "popularizer of science." It has brought me a good deal of pleasure, even if one's view of this type of transmittal of knowledge is not without a considerable degree of criticism. In the final analysis, however, the failings of popularization are very often those of education itself - the pitfalls that await me in the practice of my profession are the same as those that lie in wait for educators. And so, as I talk about popularization, I hope that you will bear the parallel in mind.

Let us begin with an anecdote ...
Last fall, when the publishing house Québec Science decided to bring out a new edition of the book "Face au nucléaire," I was invited to say a few words about it on the CBC French-language television variety show Midi plus. As we were preparing the interview, the interviewer suddenly asked, in a tone almost of relief: "Pierre Sormany, is this book finally going to tell us what to think about nuclear energy?" I tried to explain to her that the book had quite a different purpose, namely to provide the individual with all the elements needed for a personal choice, to which she replied: "But we have neither the means nor the training to make that sort of choice... . It seems to me that we elect people to do that, people who have access to all the documentation. So why don't they make whatever decisions are required?"

This anecdote, which is a little depressing for a popularizer of science, does nevertheless reflect a certain consensus within society, a consensus which in turn reflects the full extent of the myth of expertise. At first glance this is not particularly serious. After all, when the politicians entrust the choice of final recommendations, which will subsequently be followed almost to the letter, to a Royal Commission, such as the recent Porter Commission on Nuclear Energy in Ontario, they are acting in precisely the same way as the television show host: they are asking a number of experts, who supposedly have the expertise, to make a Solomon-like judgement, on the basis of all the available evidence, on behalf of all the elements of society involved. To some extent the politicians are abdicating their responsibility to make the choice.

The myth of expertise unfortunately frequently camouflages an insidious value judgment which, though rarely stated, is a direct result of the conditioning imparted by our educational system. It holds that, regardless of the contribution of the sociologists, anthropologists, semioticians, political scientists, philosophers and other champions of the soft, approximative sciences, it is the ultimate responsibility of the technicians and the experts in the True Sciences, (those that are termed the "exact" sciences), to provide the measurable elements which alone carry any weight in the ultimate decision. A de facto hierarchy has been established between the discursive sciences, whose purpose is the reassuring of the collective unconscious and the provision of cannon-fodder for journalistic broadsides, and the empirical sciences, to the beat of which the armies of technocrats march.

The result is that society's coordinates today are defined by technicians who lack the training to do so (how many science graduates have taken courses in history or sociology beyond high school?). Society in turn is not in a position to dispute the technicians' dicta, since the average citizen without a science degree is incapable of judging the correctness of technical arguments put forward by an engineer. I object both to the lack of social training on the part of the engineer and the lack of technical training on the part of the average citizen. The result of this dual deficiency is dramatic in terms of major projects and policies.

The gulf stems directly from the school system. Once it has been drummed into them that science, and by that I mean "true" science, is the path taken by the best students, the "stars," that it provides the key to Knowledge and even to Truth with a capital "T", students who encounter difficulties end up by humbly admitting that they "have never had a gift for mathematics." Sometimes they develop a degree of distrust of the techniques, but when confronted with raw scientific data they exhibit a simple faith: it is true because Science says so! Other students however, who have a greater affinity for the sciences, not only develop at times a scorn for social matters, but always adopt the attitude of a young Pee Wee hockey player to a Guy Lafleur: one does not dispute a myth, one identifies with it and makes it one's own.

In this context, popularization has the defect (as is frequently the case with traditional education as well) of introducing scientific certainties. We learn that the activities of the researcher are intended to increase the sum total of our knowledge, to ascertain reality and to establish a certain kind of truth. It is never clearly explained that the entire scientific method is based on ignorance: not on certainties, but on methodical doubt, on an inherent scepticism. The researcher's work may never establish the certainty, since hundreds of successful experiments can never prove that an exception will not appear somewhere at some time. On the contrary, a single contradictory result is sufficient to indicate that an idea is wrong. This is why all the work aimed at confirming Einstein's theories of general relativity is conceived in the reverse; with almost masochistic passion, researchers attempt to prove that Einstein was wrong, and only the repeated failure of all experiments ultimately creates the impression that, after all, he was right. But if a single result were discordant, all the mathematicians would have to sharpen their pencils. In science, it is the experiment that reintroduces doubt and it is ignorance that is always the most fertile source. Every scientific fact awaits the evidence that will disprove it.

This, however, is almost never mentioned in popular texts: is it stated sometimes in science courses?

Popular texts fairly frequently contain a fundamental error regarding scientific subject matter. I read recently in the American magazine Science Digest an article by the excellent writer Isaac Asimov on the search for fundamental particles. The article was entitled "What is Matter Made of?," and reviewed the history of the indivisible atom, up to the discovery of subatomic particles, and then of quarks and leptons, and asked the question whether an even more basic subunit might not soon be discovered. Nowhere, however, did the author explain that what is called a "particle" is in fact a physical manifestation that is known only through its behaviour and its interactions. What is called "charge," "mass," "spin" or any other descriptive term is no more than a quantified evaluation of "potential behaviour." The article should have been entitled "How Does Matter Behave?," at which point it would no longer have been surprising to find that the infinite increase in the energy involved in interactions reveals new behavioural structures. This concept of the nature of physics would doubtless have seemed strange to physicists during the last century, but it can no longer be ignored today. The descriptive models we possess of the world are incontestably useful, in that they give us a comprehensible picture of what happens between the interactions, but, like Freud's various areas of the brain or Marx's social classes, they are no more than simplified pictures, mental constructs that are useful to the extent that they make it possible to predict with accuracy. It is rarely mentioned in popular texts that the exact sciences are also behavioural sciences! And in reading recent literature on the conceptual problems of quantum mechanics, in which some physicists have rediscovered Zen Buddhism through the behaviour of photons, I have observed a fundamental misconception amongst these physicists regarding the nature of a physical model, the limits of its validity, the nature of the behaviour that can be observed and so on. This I find worrying: if physicists themselves are incapable of understanding the limits of validity of the tools they use, how can the general public be expected to understand?

In fact, the entire process of questioning science has been excluded from the learning process, both in school and thereafter. How many teachers of physics, chemistry or biology have, in the course of their studies, covered even the rudiments of the history of science? How many have had an opportunity to discuss the epistemological foundations of what they teach?

Placing things in their historical context may appear easier in a popular text, which is less oriented towards formulae and tends more to the anecdotal than a university course. If, however, a researcher's approach is linked too closely with the formulation of his or her hypotheses or new "discoveries," the opposite effect is often obtained: by associating the problem too closely with the proposed solution, the two become inextricably linked in the reader's mind, so that the problem appears henceforth as a "proof" that substantiates the answer. If a researcher proposes a new theory to explain cancer, this will inevitably be presented in the form of a new hypothesis outlining the reasons behind its formulation, amounting to an argument for the new idea. This is quite normal, but for the reader, the problem becomes the proof of the answer.

Popularization is in the final analysis a treatise, disembodied and divorced from practical application, a treatise which celebrates the myth, gains converts and convinces its audience. It is a treatise that serves ultimately to hand down the dogma. But if we look at education, we see that the laboratories, which should provide the framework for the introduction of practical applications, almost always associate problems and solutions in an automatic approach which links the model indisputably to the questions that gave rise to it. Science teaching, whether in the classroom or in the laboratory, is thus also the transmittal of dogma.

As a celebration of the myth of expertise, faith in the dogma rather than in questioning, and popularization, isolated increasingly from experimentation, is in danger of achieving the opposite of what it claims to do by widening the gulf between the researcher, the person who knows, and the passive listener. It has happened so many times that I have been told, with regard to a text with which I was generally satisfied, "Your text is interesting. You must be awfully knowledgeable to write all that!" By making this knowledge accessible, I have accentuated the reader's admiration of the scientist he believes me to be. I had substituted a grain of the myth of expertise for an ounce of the mystery of science.

This myth sometimes has elements of tragedy. The more the emphasis is placed on the expertise required to combat sickness, the more the reader becomes convinced that this responsibility must be entrusted to a doctor. Whereas a common cold, which is often popularly termed 'flu,' can be cured by the expedient of large glasses of water, aspirin and mustard plaster, who would believe that the same treatment would be indicated in the case of an acute rhinoviral infection of the upper respiratory passages? Far from reinforcing the independence of the individual, such information can doom one to dependence - a credulous dependence in awe of the scientist. Who would dare to cast doubt on the words of someone who has manifested the incomparable kindness of leading one out of the slough of ignorance? Scientific information, like political or sports information, creates its own stars. When it becomes popularization, scientific knowledge itself assumes the mantle of stardom, and stars are not disputed, they are appropriated.

In the same way as science teaching, perhaps, although to a lesser extent, popularization can be dangerous. The new concepts that it introduces only very rarely succeed in dislodging established ideas, but are superimposed on them more or less successfully. The acquisition of scientific knowledge, however, presupposes a complete break with the prescientific vision of the world, with all the integrated scheme of response with which the individual has been made familiar since childhood. He or she must learn to reject the "natural" explanation in favour of the scientific behavioural model. The break is often a painful one. More often than not, the individual is therefore content to integrate this new knowledge into a previous world view, in such a way that science is juxtaposed with ignorance, rather than replacing it. This is not substitution but accommodation. At best, this solution results in a sort of mental schizophrenia, in which the science student may be perfectly capable of solving the most complex equations while retaining an extremely childish vision of the world. After all, was not Newton himself to some extent this sort of person? At worst, however, it results in poorly integrated theories composed of equal parts of science and superstition, where science reinforces the very prejudices it is supposed to combat. It is entirely probable that popularization has to share part of the responsibility for the current flowering of the pseudo-sciences!

Popularization does, nevertheless, have positive effects as well, and the entire picture is not black. It provides useful factual information, some of it essential; it provides a flow of information between scientists themselves; it provides the necessary caveats; it provides information which is more directly "functional," and yet appeals to the imagination, the sense of the spectacular, which is also an integral part of the dissemination of information in our society. In terms of the spread of knowledge, however, the limitations are dramatic. Regardless of how hard the popularizer searches to fill in the gaps by producing texts that create doubts and incite critical reflection, the readers continue to need reassurance and certainties. In any event, they will retain from a written text only that which they want to retain, and that, most often, is what is reassuring. On the other hand, if he or she has severed connections with scientific knowledge since leaving high school, nothing will be retained, because he or she will virtually never read popular texts.

Sooner or later, therefore, it is the educational system that must bear the burden of responsibility for the impotence of popularization.

I have no solutions to propose to you today: at least, I have neither a miracle cure-all nor a partial solution any different from those already formulated on a number of occasions by yourselves. I would however like to apply some of my thoughts on popularization to education. In order to transmit scientific understanding and culture in the fullest sense, beyond mere mastery of mathematical tools and a few theorems, science teaching must also be approach-oriented, encourage doubt, and set a premium on the agony of uncertainty rather than on the safety of closed systems; place greater emphasis on questioning and on the limits to the validity of the models proposed and the mathematical tools that have been developed, and strive constantly to keep scientific data rooted in their historical context, which alone can explain the underlying perspectives.

Education should perhaps also borrow some of the popularizer's techniques and attempt to "hook" students through those things that are important to them. In history, this works fine: one can begin with Newton's concerns in such a way that the student and reader can be brought to share them. More frequently, however, the major principles of modern science can best be presented by analogy with contemporary objects and situations. The analogy of driving a car, for example, is excellent for introducing the principles of energy conservation and transformation. An industrial visit to an electrolysis room is far more effective than texts and diagrams for explaining (or at least introducing) the principles. In short, we should return to the "object lesson."

Before we integrate these new approaches, however, we should perhaps decide not to offer any more introductory science courses intended to prepare the better students for the following course; the next course itself being perhaps an introduction to the tools necessary to master a third level of specialization, with the whole system leading straight to undergraduate or even postgraduate degrees. Although this system probably produces very good scientists, it nevertheless sacrifices all the others, and even the most effective popularization will never win them back. It would perhaps be better to regard each course from the outset as a cultural adventure in itself and attempt to teach an approach, a critical attitude. There will still be time, as the students delve further into the approach, to provide them with the more complex tools and formulae needed for scientific experimentation and mastering engineering techniques.

IV. CONCLUDING STATEMENT

Mr. Gilbert Lannoy

Physics Teacher
Commission scolaire des Mille-Iles

I believe it was La Bruyère who said, that as soon as the world came into existence, everything had been said or written. Rest assured: I think he was exaggerating and I would not insult you by sending you home in such a cavalier fashion! The rhetorical exercise in which I am compelled to engage, namely synthesis, seems to me to be all the more difficult in that there has been neither a thesis nor an antithesis. The speakers have all covered the precise topics that were assigned to them and have dealt both with past history and future prospects. I must therefore ask your forgiveness in advance for the lack of objectivity in this report.

The symposium began this morning with a jump back into the past in order to give the participants an historical overview of science teaching in Québec. Mr. Alexander Liutec showed us the evolution of educational curricula and structures in a systematic way with a series of charts.

Science teaching in the 1940s and 1950s consisted largely of theoretical knowledge arranged meticulously in a textbook, to be memorized. Use of the laboratory was very rare, scientific method either nonexistent or virtually so; the main pursuit was that of the correct answer. Around 1963, the Parent Report brought about some far-reaching educational reforms and called for an upgrading of science teaching, both in quantitative terms (the report recommended daily science classes at the primary and secondary levels) and in qualitative terms (it asserted the priority of the scientific method, equally applicable to the natural sciences and to other subjects). From then on, training has been more important than information and method more important than knowledge. The learning of course content has been superseded and become secondary.

Faced with the impossibility of producing indigenous Québec educational tools quickly from scratch, the reformers adopted, without restrictions, well-known American methods (IPS, ChemStudy, PSSC, BSCS, and so on), which had been designed by scientists to produce better researchers.* Laboratory work was the first priority, difficult points in the subject matter were illustrated by films; the textbook was no longer a compendium of formulae, laws and recipes - it demonstrated and suggested models of rational reasoning.

At the beginning of the 1970s science teaching succumbed to the influence of the American behaviourists led by Bloom and Mager. The goal at the time was to circumscribe the curriculum as exactly as possible and to subdivide it into a large number of single, interconnected sections that were easily absorbed by the students and "scientifically" measurable by their teachers.

These periodic course changes notwithstanding, science teaching never seemed to inspire the enthusiasm of the majority of the students, who found the courses too difficult and boring. Not only that, they did not take many of them - apart from ecology, there was no compulsory science course at the secondary level. What is more, the new educational system recently unveiled by the Minister of Education, Mr. Camille Laurin, is not likely to succeed in upgrading the status of science in the eyes of Québec's children and citizens!

Despite a certain veneer of optimism, these worries are shared by Mrs. Graziella Lévy, who was astonished that the first official natural science curriculum at the primary level did not appear until 1970. Prior to that there was not very much. She drew us a brilliant caricature of the development of science teaching in Québec, which went from fashion to fashion, from the formal and descriptive pattern prior to the 1960s to a computerized model of objectives and subobjectives:

. before 1960: KNOWLEDGE = CONTENT OF TEXTBOOK
. during the 1960s: KNOWLEDGE = METHODS (especially American ones)
. during the 1970s: KNOWLEDGE = ATTAINMENT OF OBJECTIVES.

* Introductory Physical Science; ChemStudy; Physical Science Study Committee; Biological Science Curriculum Study.

She regards the present situation of science teaching as precarious. There seem to be a number of signs that bode ill, such as budget cuts, reductions in timetables, student disillusionment, and desertion by teachers. Above all, there is the lack at the primary level of any training for science teachers; after the secondary level, they have rarely taken a science course. Advanced training in science is virtually nonexistent.

Mrs. Lévy nevertheless remains optimistic. Apart from problems related to methods and structures, she is convinced that the prime need is to change the attitudes of parents and teachers, especially. For her the child will always remain as eager, if not more so than before, to discover its natural and human environments and to understand them.

Dr. Louis Ste-Marie concludes that science teaching in Québec reached a stage of bankruptcy following the Parent reforms. His study, EVALENSCI, was designed to evaluate the extent to which the stated objectives were achieved for science teaching at the secondary level by the programs of the Department of Education of Québec (MEQ) and by the authors of the textbooks in use. It was intended to measure whether students who had taken several science courses had experienced progress or stagnation, or even regression, with regard to:

1. the student's intellectual independence;
2. the student's social integration;
3. the student's social and emotional development.

The conclusions were as follows:

a) The students' intellectual rigour, capability in the formulation of hypotheses and creativity improved slightly, regardless of the textbooks used. At the very least, misconceptions were rejected.

b) As far as the human and social values of science are concerned, the courses seem to divert students from scientific careers. Whether it was physics, chemistry or biology, students change their attitudes and become less and less interested, especially those who are people-oriented.

c) The students' need for security is not met; with the exception of those who use the Keller method, science teachers do not succeed in imbuing their students with confidence because of excessively low grades, the presentation of abstract concepts, laboratory work and the method of teaching by objectives.

Dr. Ste-Marie recommended that a new science course be designed specifically for those students who are not planning a career in science. He believes that a course which would as far as possible integrate science, technology, the history and sociology of science would succeed in recovering the floating mass of students who are now fleeing science courses because they perceive them as elitist.

We wonder, however, why this study refrained voluntarily from analyzing the influence of teachers' behaviour, training and interests. These data would, in our view, have provided valuable additional indicators, since teachers are, after all, the primary channel for the transmission of knowledge about science at school. Their influence appears to us to be paramount.

This is, moreover, the opinion of Dr. Graeme Welch of the John Abbott CEGEP, who places the lion's share of the blame for the failure of science teaching in Québec on the shoulders of the teachers. His analysis, which borrowed its style from science-fiction, mercilessly dissected the following elements:

- a decline in the professional standards of science teachers because of increasing age, resistance to change and training, and unionization;
- a lowering of the quality of textbooks, which he terms decadent because of their desire to please everyone;
- a dilution of knowledge: too little is taught about too many things to too many people;
- neither measurements nor evaluations are significant;

- gaps in basic education, especially competence in the mother tongue.

Dr. Welch believes that students are bored at school because of a lack of intellectual stimulation. He recommends a return to basics: strengthening of the communications tool par excellence, the mother tongue; specialization; the organization of scientific activities. This uncompromising set of demands appeared to find agreement among the science teachers present.

They were shaken again by the rather unorthodox suggestions of Mr. Marcel Risi, the commercial director of the Centre de la recherche industrielle du Québec (CRIQ). He questioned head-on the value of science teaching as presently practised. The citizens of tomorrow will have to live in a highly fluid environment in which the idea of change is central. The most appropriate form of adaptation to this environment will therefore not be the result of a rational process, but rather that of creativity which is a function of knowledge, imagination and the environment.

In what appeared to be a very artificial way, Mr. Risi distinguished between two creative methods:

- the speculative approach, which involves the search for knowledge leading to laws and paradigms;
- the active approach, which involves solutions to problems in response to needs created by an evolving environment.

Science teachers are always some way behind the world of industry and prefer the first method: as a result, according to Mr. Risi, they are experiencing increasing difficulties in capturing the imagination of young people. They should be taking the opposite course of abandoning the experimental scientific method in its canonical form (a surprising statement from a physicist?) in favour of having their students imagine and define the problems rather than looking for solutions. From there it is but a short step to institutionalized insecurity, a permanent anguish similar to that experienced by our ancestors in their caves. Why not? Perhaps this is the key to human evolution, with science no longer being perceived as the traditional power over people and things but rather as the active striving for existential growth and the maximum development of human potential.

Dr. Jacques Désautels, the author of the shocker École + Science = Échec summarized briefly some of the criticisms of the present system by pointing out that the school is cast in society's image, that it therefore reproduces social classes, that science teaching is based primarily on the training of a scientific elite and so on. He postulated that the future of science teaching in Québec will be a part of a blueprint for a new society developed at the wish of its citizens. Hence the fundamental question: what sort of scientific education for what sort of society?

Dr. Désautels then unfolded a vision of a future society that would be less centralized, more ecology-oriented, more imaginative and less materialistic. This would necessitate radical changes in the educational attitudes and strategies of science teachers, who should:

- approach social problems more critically;
- be more committed and not content merely to transmit ready-made knowledge;
- demythologize technology;
- have a holistic view of the world;
- act collectively to free themselves from their feeling of impotence when confronted with world problems;
- practise an educational philosophy based on awareness, meaningfulness, autodidacticism, creativity and interdisciplinary integration.

Dr. Désautels invited teachers to become more involved in their community, because, by virtue of their position, they are prime agents of change.

Finally Dr. Germain Gauthier, Vice-Président in charge of teaching and research at the Université du Québec, turned the spotlight on the privileged relationship between teacher and student in the chain of the transmission of knowledge. He identified three problems in terms of the foreseeable direction of society which directly involve science teaching:

- the leveling-off and decline in student enrolment will result in a drop in the number of teachers and an increase in their ages;
- school and college are no longer the only institutions imparting scientific information, particularly when one thinks of the remarkable development of leisure-time scientific organizations in Québec;
- science and technology are increasingly interdependent; the interval between a discovery and its application has shrunk drastically.

By way of remedies, Dr. Gauthier proposes:

a) on-going and less compartmentalized training and advanced-training programs for teachers;

b) a return to basics: the primary function of the school should be training, because information can be disseminated much more effectively by the media (radio, television, magazines and newspapers);

c) a greater degree of realism in science curricula, especially in terms of the integration of science and technology.

Perhaps these few remedies will prove sufficient to revitalize science teaching now in the doldrums.

In conclusion, we can say that this symposium has not provided any miracle cures for the crisis facing science teaching in Québec. It has nevertheless made it possible to identify a number of serious problems and to propose the outlines of solutions to them. There were extensive discussions of content, curricula, methods, and, in particular, attitudes that need to be changed. How? By the sacrosanct experimental method, which produces more or less transitory certainties, or by Mr. Risi's method of systematic doubt? It is up to the science teachers themselves to decide.

V. SUMMARY OF SYMPOSIUM PRESENTATIONS AND DISCUSSIONS

The symposium provided a variety of viewpoints on science instruction in Québec. It gave the participants an opportunity to examine the topic from an historical standpoint, to look at its current state and related problems, and to consider its future.

Part One: Perspectives on the background and present state of Québec science education

FIRST SPEAKER

Dr. Louis Ste-Marie
Professor in the faculty of education
Université de Montréal

Dr. Ste-Marie's presentation focused on the study he has been conducting since 1974, in which he is assessing science instruction at the secondary school level. The results of the study will appear in the final report of the EVALENSCI research team.

Dr. Ste-Marie began by setting forth the Department of Education's three main objectives.* They are:

1. to contribute to the development of the student's intellectual independence;
2. to facilitate his or her integration into society; and
3. to contribute to his or her social and emotional growth.

As regards the first objective, results of the study on over 4200 students in secondary IV indicate that students improve in their ability to reason scientifically and to think critically over the course of a school year. The first objective is therefore considered to be achieved. On the other hand, this is far from the case with respect to integrating the student into society. Even the HPP (Harvard Project Physics) physics program, developed for students not taking science, fails to make the students aware of the human and social values of science.

* Formulated on the basis of available official documents.

The third objective (the student's social and emotional growth), has not been achieved either. Motivation and satisfaction with respect to science courses remain low. It was noted that improvement could be brought about in this area through the use of individually oriented instructional techniques.

Dr. Ste-Marie suggested some explanations for this. Now that science is well established in society, we should perhaps stop presenting only the inside of the structure of science. We should open the doors and step out to have a look at science in nature and in its social surroundings. For the future, he proposed a course in the history and sociology of science.

Questions and comments

First commentator: Mr. Jacques Labadie, high school science teacher, Sophie-Barat School, Montréal:

> "I would like to know whether you included students who took science courses in elementary school."

Dr. Ste-Marie's reply:

> "No. The study considered instruction at the secondary IV level only."

Second commentator: Mr. Claude Villeneuve, science teacher at Collège Saint Félicien:

> "Do you feel that on-going training rather than a somewhat artificial course should be the means of teaching the social aspects of science; that learning situations should start from the experiences and social relationships of the student and move toward an explanation of the scientific structure?"

Response:

> "I do not feel we should drop courses more specifically aimed at those who are heading into science. But we are forgetting part of the population. We do not want to alter the outlook and nature of students who are oriented more toward people than things, but rather, to adapt a course for them. Even the HPP, despite its

attempt to do so, is a failure. It tells the story of the structure. What we need to do is get more outside of it."

Mr. Villeneuve:

"At what level do you see this course or group of courses being given?"

Dr. Ste-Marie:

"I see it at the end of high school."

Third commentator: Mr. Desgagné, teacher at the St-Aubin composite high school:

"Instruction in science at the secondary IV and V levels is optional. Do you not believe that a science course should be included in the normal program, that is, be made compulsory?"

Response:

"Making courses optional or compulsory is a matter of general policy. The teaching body has another policy: courses have to be sold as well. Requiring everyone to take a course in order to have customers is too easy. If an effort is made to "sell" the course, there will be customers, and more respect will have been paid to the students than if the courses had been made compulsory. One science course must be taken at the beginning of high school. However, I feel that there can be options at the end of high school."

Mr. Desgagné:

"I feel there is as much dissatisfaction with the other subjects taught in high school - mathematics, French, history - as there is with science. I feel that your conclusions with respect to science also apply to all the other subjects."

Dr. Ste-Marie:

"I won't say that I agree. Perhaps it is true. Perhaps it is a flaw inherent in the fact that education is divided by subject matter. However, the problem that we are dealing with this morning is much broader."

Fourth commentator: Mr. Jacques Lalande, science teacher with the Saint-Jérôme school board:

"Am I correct in understanding that, in your view, we should not drop science courses for those planning a career in science?"

Dr. Ste-Marie:

"Yes. Students heading towards the sciences want to have a better look at the inside of the structure. This does not mean, however, that they also should not look outside it."

Mr. Lalande:

"I take it then that you do not agree with the Department of Education's current position that there is to be only one program for everyone taking high school courses."

Dr. Ste-Marie:

"That is correct."

Fifth commentator: Mr. Henri Grenier, chemistry teacher at the DuRocher composite school, Grand-mère:

Mr. Grenier said that science could not be separated from other subjects, particularly when we come to formulate conclusions and propositions. A student's interest in mathematics and the ability to understand and express himself or herself in good French affect his or her ability in science. Mr. Grenier noted that interest wanes between secondary I and V, and that efforts have failed not only in the area of science, but in the field of education.

Dr. Ste-Marie:

"Everyone is passing the buck. I am not in favour of revolutions in education. No matter what reforms we undertake, we have to carry along what we had before. The school system is sick, but we must proceed cautiously. Let us solve the problems in science courses first."

Mr. Grenier:

"You mentioned the study at the college level (Keller method of instruction). I have found comparing colleges and high schools to be dangerous, because of the differences in maturity of the students at the two levels."

Dr. Ste-Marie:

"I used that example simply to illustrate that science can be humanized considerably for both nonscientists and future scientists alike, when a good teaching method is used."

Sixth commentator: Mr. Gilbert Lannoy, science teacher with the Mille-Iles school board:

"You do not include teachers in your study EVALENSCI. They are the principle medium for the courses. It would have been interesting to study teachers' academic and professional training, their classroom teaching style (authoritarian or unstructured) and so forth. A good teaching method can be completely discredited by a teacher who does not understand it or has not learned its fundamental principles."

Dr. Ste-Marie:

"The direction taken by the research team did not include studying the behaviour of teachers, even though it was interesting to do so. We analyzed only one of the elements."

Seventh commentator: Mr. Juan Cobo, science teacher, Chomedey-Laval:

"Do you not think that your study diagnoses a symptom and not the real problem? If science courses are to teach discipline and critical thinking, how can this goal be reached in a society in which the student is subjected to the influence of television, where his or her role is passive, without discipline or criticism? Even if we change the programs, we will not change society."

Dr. Ste-Marie:

"Let us adapt the programs to society. It is wrong to say that our society completely lacks discipline. I did not want to present a picture of our society. It is constantly changing and has changed considerably over the past twenty years."

SECOND SPEAKER

Mrs. Graziella Lévy
Pedagogical consultant for elementary science
Taillon school board

Mrs. Lévy described the revival of science instruction in the 1970s as changing the equation learning = textbook to learning = method. The equation is changing again with the new programs of the 1980s to learning = objectives.

These dramatic changes are perhaps the result of the protests of the 1960s and of the ever-widening gap between school and life.

Mrs. Lévy felt that the student should now be developed rather than informed. She was also concerned about the training of teachers, particularly at the primary level.

Questions and comments

First commentator - Mr. Jacques Labadie

"What proportion of teachers with your school board teach science?"

Mrs. Lévy:

"About eighty-five per cent."

Mr. Labadie:

"I am delighted. In Montréal a number of parents and teachers tell me that a child can reach fourth grade without ever having had science. In general, there are a lot of gaps in Québec in this regard.

Second commentator - Jean-Pascal Souque, Collège Jésus-Marie

"Do you know what percentage of women are teaching at the primary level in the province?"

Mrs. Lévy:

"No. In my school board, I believe that ten of a total of 200 teachers are male.

Mr. Souque:

"Women are pretty solidly represented in elementary education. At the Science Council workshop on the status of women in science education (February 1981), a number of experts indicated that the image of science in society does not include women. Women are largely underrepresented both in education and in scientific activities. How is science portrayed by science teachers at the primary level, and, as pedagogical adviser, have you thought of ways to solve the problem?"

Mrs. Lévy:

"This problem existed long before the implementation of the science program in my school board (1972). When I arrived, in 1973, my first endeavour was to demythologize science. Science is understanding the world, nothing more."

Third commentator - Mr. Marc Pelletier from the Université de Montréal:

Mr. Pelletier wanted to corroborate Mrs. Lévy's statements. While he was pedagogical adviser for science education at the primary level, he noted that some teachers were intimidated by science. Teachers were shaken by all the program reforms - in French, mathematics, catechism and science alike. He wanted to point out teachers' lack of training. He felt that the course proposed by Dr. Ste-Marie, the history and sociology of science, would be welcomed not only by students in high school, but also by those who teach science.

Mrs. Lévy:

> "I agree with Dr. Ste-Marie on the following point as well. The pedagogical approach must be instilled in future teachers in order to win over students in high school. I must also point out that there is a big job ahead with respect to informing the parents, because they do not yet understand what science provides."

Fourth commentator - Mrs. Pearl Francoeur, professor in the faculty of education, McGill University:

Mrs. Francoeur felt that we have excellent textbooks for teaching science at the primary and secondary levels. The teachers who had been students of science pedagogy in the past six or seven years had weak backgrounds in sciences. Their students came to them with the equivalent of one science course at the secondary level. This gap in their education is very serious.

According to Mrs. Francoeur, certain studies have shown that the quality of a science course was higher if the teacher had taken a number of science courses during his or her training. She felt the problem lay not with textbooks or methods, but with the training of the teachers.

THIRD SPEAKER

Mr. Alexander Liutec
Vice-Principal
Chambly County High School

Mr. Liutec began by referring to the programs of the 1940s and 1950s. Laboratories did not play an important role then. Students were not really considered capable of making scientific observations. In high school, science amounted to memorizing certain facts and reproducing them on request.

Then came the 1950s and 1960s and the upheavals in the educational system, particularly following the report of the Parent commission. Laboratory work was once again in favour. During the 1960s the Americans invested considerable human and financial resources in the development of new teaching methods and texts. At the beginning of the 1970s, schools offered a broader choice of science courses. More students were enrolled in one-year courses than in two-year ones.

Today it appears that our science students are desparately in need of a program that will allow them to use their knowledge and abilities in constructive projects. A student who likes music can always play with the school band, but is there a similar opportunity for the student who likes science?

FOURTH SPEAKER

Mr. Marcel Risi
Commercial Director
Centre de recherche industrielle du Québec

Mr. Risi's talk concerned the teaching of science and the needs of industry. He said that a problem can be solved in one of two ways. The first approach stops the machine and studies the system; the second comes up with a new solution using knowledge gained previously.

In industry, competence will be linked increasingly to creativity and innovation. The former is itself the function of three factors: knowledge, imagination and environment.

Education should affect mainly the scope and focus of knowledge, and the control and use of the imagination so as to develop the capabilities of the individual, who can then change his or her environment.

While the student must always be given a solid grounding in scientific knowledge, he or she must also be helped to see the changing environment in a realistic fashion and encouraged to use his or her creative abilities.

Mr. Risi felt that Mr. Souque and Mr. Désautels had put forward the beginnings of a solution when they suggested a course of real cultural change.

Questions and comments

First commentator - Mr. Jacques Lalande, St-Jérôme school board:

Mr. Lalande did not want people to conclude from Mr. Risi's remarks that studying science required no effort. It is all very well to challenge the system, but one first has to understand it.

Mr. Risi:

> "I was talking to teachers this morning. I did not say that knowledge should not be passed on to the students; I did not say this knowledge was easily assimilated. I said there are three essential things to be developed in a general process: a very good perception of the environment, a good knowledge of the state of technology, and creative abilities. The student must be prepared to learn what he or she will need to know once he or she is on the labour market."

Second commentator - Mr. Juan Cobo, Chomedey-Laval:

"I believe industry needs creative thinkers. But 99 per cent of its work force is composed of worker bees, who will work to enable the companies to make their profits."

Mr. Risi:

"Worker bees work because it is in their genes. Humans have the ability to change their work and make it interesting. We are judging industry too quickly when we say that it exists only to exploit. I do not believe this is generally true. Industry is not opposed to the notion of creativity... . I think creativity also has a role in changing behaviour in industry."

Third commentator - Mr. Gilbert Lannoy, Mille-Iles school board:

"Earlier, on the board, you outlined two approaches to learning: one, speculative, and the other, active, in response to life's problems. Do you not feel that the distinction is artificial? The history of science is full of examples of discoveries being made in response to problems... . Why distort the experimental method and represent it as sterile?"

Mr. Risi:

"I did say both approaches were equally creative. I spoke this morning about the curious and the questioners. Happily, I agree with you that there are geniuses. The caveman developed tools for hunting and feeding himself without understanding the laws of inertia and projectiles. You have been talking about the reverse - the Xerox process, for example, used in photocopiers, was developed in 1933. It was not until after the war that they discovered the problem that the solution fitted. Such technological discoveries might happen 10 times in 100 years. Looking at one's surroundings does not lead to this sort of thing. It takes a stroke of genius. It is like building a cathedral."

Mr. Lannoy:

"Let us talk now about anxiety. You are advocating insecurity. But has scientific activity not been a response to people's fundamental fear? Dr. Ste-Marie talked earlier about insecurity, even in a well-structured course. Are we now going to offer our young people anxiety?"

Mr. Risi:

"There are evolutionary phenomena. I have encountered three phenomena: religion as a source of security, science as a source of security and economics as a source of security, where, in econometric equations, we are offered a guarantee of future well-being.

None of these provide long-term solutions. We must continually develop new solutions to new problems. Research into new problems and new solutions must be on-going."

Fourth commentator - Mr. Teolindo Gonzalez, GEGEP Montmorency:

"How can a teacher put this teaching theory into practice in everyday life?

Mr. Risi:

"By refusing to teach."

Mr. Gonzalez:

"Refusing to teach is too simple a solution. How would you approach a physics course, for example?"

Mr. Risi:

"I feel that we must first get rid of the notion of ratios (one teacher to so many pupils) and demystify programs. We must stop setting up learning processes with content objectives, and, instead, weight these objectives not according to what the students know, but according to their ability to learn other things in the future. An attempt must be made to remove education from its administrative framework.

We must teach not what the student can read in a book, but the intellectual process, the approach."

Mr. Gonzalez:

"What if the student says that he or she does not want to learn according to this anxiety-arousing approach?"

Mr. Risi:

"Behaviour problems are not resolved by management systems. It is a known fact that people like things the way they are. They must be made to realize that changes are beneficial for their being. If I had the solution, I would probably be deputy minister of education."

Fifth commentator - Mr. Claude Villeneuve, Saint-Félicien college:

Mr. Villeneuve said that teachers should avoid answering questions that students do not ask of themselves. He felt that the role of the teacher is to lead the student into a situation in which he or she feels uncomfortable faced with his or her ignorance. This way the teacher becomes a sort of special instrument for passing on the knowledge the student needs. The latter then learns much more.

Mr. Risi agreed with the above.

A sixth commentator - Mr. Dalys, a high school teacher on the South Shore: -

Mr. Dalys periodically asks his students questions on newspaper or magazine articles or television broadcasts on science. He had reached the conclusion that science is blamed for all of society's evils: pollution, destruction of the earth and so on.

Mr. Dalys felt that the first job of science teachers is to distinguish between the various facets of science and technology. The scientific method has deep roots, sustained by disciplined minds. Science education has perhaps neglected to get this across.

Mrs. Lévy:

> "Rather than answer directly, I will make a general remark. It is very clear to me that learning content is absolutely out of the question today. We must learn how to learn."

Part Two: Future directions for science teaching in Québec

FIRST SPEAKER

Dr. Jacques Désautels
Professor in the Faculty of Education
Université Laval

Professor Désautels said that raising questions about the future of science instruction in Québec meant raising questions about the future of our society.

It is at the high school level that an awareness of science comes into play in our society, because the vast majority of our population has no further contact with science instruction beyond this level.

In short, the role of science instruction to date has been as follows: to prepare a scientific elite, preventing the majority from acquiring a real awareness of science.

Professor Désautels asked what the society of the future would be like. Would it be the inevitable result of the continuation of current socioeconomic tendencies or something that could be fashioned to suit our needs?

He outlined some of the characteristics of a better society. It might be: more decentralized, more ecological, more technologically adapted to collectively defined needs and so forth.

Professor Désautels proposed a number of broad focuses for science instructions, the fostering of a critical view of society, demystification of science and its great names, promotion of individual and group development in knowledge and know-how, the fostering of an overall view of the world and so forth, all through the use of educational techniques that involve consciousness raising, individual learning and the development of creativity among others.

Professor Désautels felt that such a teaching program would be possible if teachers became aware of their social obligation, the lack of cooperation among them, and their ability to alter the course of evolution.

Questions and comments

First commentator - Mr. Gonzalez, CEGEP Montmorency:

"How do you envisage a physics course, for example, given by a physics teacher, in a high school of the future, if these two still exist?"

Professor Désautels:

"Instead of always working on what the books contain, we should promote projects like the construction of a greenhouse, as they did at CEGEP St-Jean-sur-Richelieu. In museums of science and technology of the future, we could look at the development of technological items and pass judgement on what technology offers us. In short, there is room to manoeuvre in our social system."

Second commentator - Mr. Jacques Lalande, physics teacher with the St-Jérôme school board:

"How does the development of a scientific elite interfere with the development of science education for the general population?"

Professor Désautels:

"I never said that we should take the PSSC away from those who want to pursue a career in science. I said that, in the past fifteen years, they have been treated specially, to the detriment of everyone. However, the students in this category often get along, in any case, even if they have poor equipment. But if we teach high school science without a critical approach, we are training people to let the minority make decisions for the majority.

More students should be equipped to take part in society. However, this presupposes a new democratic ideal. It is a problem for society; but if teachers do not get involved in it, nothing will change."

Third commentator - Mr. Paul Tourigny, engineer:

"I wonder if one of the consequences of your proposal is not to give priority to biological and even human sciences?"

Professor Désautels:

"No. I am only saying that the critical approach should be part of all teaching. We have all acted as disseminators of ready-made information, removed from social and political reality.

High school students should be given the basic tools they need to enable them to participate in a democratic society. This is in part the function of science education, but within the educational plan of a school in a community."

SECOND SPEAKER

Dr. Graeme Welch
Professor at John Abbott CEGEP

Professor Welch said that the standard of textbooks (which he considers reflect the state of science instruction), has decreased substantially over the past 20 years. At least part of this decline can be blamed on teachers. Teachers in Québec have obtained excellent working conditions for themselves, but at a cost of quality of education.

Ever-increasing knowledge has prompted teachers to include more and more subjects in already heavily laden programs. As a result, students know less and less about more and more. The most complex subjects are eliminated from the programs, enabling the least gifted students to take the course, but preventing the most gifted from developing their full potential.

Professor Welch felt that science courses should be completely rethought so that students with the greatest intellectual capacity can develop their abilities to the fullest.

Questions and comments

First commentator - Mr. Gilles Noël, physics professor, CEGEP St-Jean-sur-Richelieu:

Mr. Noël quoted the memorandum on science education prepared by Mr. Brisebois, Mr. Dubé, Mr. Pellerin and Mr. Beaudoin: "The number of hours of science courses required for admission to CEGEPs is becoming ridiculous. The reduction, since 1977, in the number of hours required from 600 to 90 represents a spectacular decline that will place Québec last among industrialized countries."

Secondly, in Québec the educational revival is based on the statement set forth in a white paper: college education does not have to be determined by what precedes it or by what prolongs it.

Mr. Noël wondered whether it was possible to have a system of education in accordance with such a principle.

Professor Welch:

"I do not feel that science is taught in sufficient depth at the college level. On the other hand, I feel that we are giving science courses to too many students. Some of them, on the basis of their course of study, have no need of information learned in courses that are university prerequisites."

Second commentator - Mr. Henri Grenier, chemistry teacher at the DuRocher composite school:

"You say that high school courses do not interest students, because they are too heavy. . . . But it has been my experience, at the Institut de technologie where the educational program was very heavy, that the less demanded of a person, the less produced. We are not going to succeed in producing better citizens by lightening high school courses.

We no longer have a French Canadian elite in the sciences, and that does not help matters any.

We have been going over the same things for the past seven or eight years. As science teachers, we really look pretty foolish with our scientific method and all."

Professor Welch:

"I hope that my comment was not interpreted as a desire to lighten science courses. If students want to take chemistry in high school, let them do so. But if they do not need it, let them learn something else."

Mr. Grenier said that high school students do not know what they need. They should not try and avoid all effort.

Professor Welch:

"Indeed. The present solution is to teach regardless. We cannot win on all sides: a choice must be made between teaching science and teaching an awareness of science."

THIRD SPEAKER

Dr. Germain Gauthier
Vice-President
Education and Research
Université du Québec

Dr. Gauthier tried to establish some of the main characteristics of the Québec socioeducational milieu between 1980 and 1990.

The first factor that will affect the future of science education in Québec in this decade is the decrease in the number of students, which will be closely followed by a decrease in the number of teachers.

Secondly, schools and colleges are not the only sources of scientific information. While science does not "sell" well in schools and colleges, it is of increasing interest to the media and it takes up more and more of the leisure time of the young and not so young.

Another trend in today's socioeducational milieu is for science and technology to move closer and closer to one another. More and more applied work is mixed in with basic research in our universities, and more and more basic research is being carried on in the large laboratories of industry.

Dr. Gauthier put forward three proposals for coming to terms with these trends: we must first promote continued training of teachers; we must also return to the primary objective, which is to form the student and help him or her to view science and technology as tools at his or her disposal, whose sense and scope are within comprehension. This approach leads the student to link science with everyday life.

Questions and comments

First commentator - Professor Bill Searles, McGill University:

Professor Searles drew some conclusions by putting the statements back in their context. He felt that educators are not analyzing the problem of program changes in sufficient depth. He felt that work already completed on the subject would serve as an excellent basis for research. With this research, educators have enough material in hand to change programs with full knowledge of the facts.

Professor Searles felt that the importance of good teaching material and of the teachers' background should be recognized. He wanted people to realize that educators have a subjective view of what is to be taught.

He felt that teachers should play a greater role in the formulation of course content. In Scotland, for example, 80 per cent of biology teachers take part in developing course programs.

Second commentator - Mr. Juan Cobo, Chomedey-Laval:

"The main problem seems to me to be the aging of the teaching body. What could be done to counter this situation?"

Dr. Gauthier:

"I do not think that the quality of an instructor's teaching diminishes because of advancing age: The important thing is that we understand the phenomenon fully and prevent any possible negative effects. In order to do this, a teacher's early training and early development should be taken into consideration."

Third commentator - Mr. Eric Devlin, Hebdo-science information service:

Mr. Devlin wanted to point out the importance of recreational science activities in science education. He felt it was a mistake to consider science courses as a private reserve. Our society lacks a long scientific tradition, and, therefore, it is important to develop science recreation and information. He also felt it was important to create a social climate that would allow science to take root in Québec through recreational and popularization activities.

APPENDIX A - PROGRAM

Québec Science Education:
Which Directions?

Symposium held 7 March 1981, at the Université de Montréal and sponsored by the Science Council of Canada and l'Association des professeurs de sciences du Québec.

9:00 a.m. Symposium Introduction

Dr. Maurice L'Abbé
Executive Director
Science Council of Canada

Mr. Claude Marineau
President
Association des professeurs de sciences du Québec

9:15 a.m. Perspectives on the Background and Present State of Québec Science Education

Dr. Louis Ste-Marie
Professor
Faculté des sciences de l'éducation
Université de Montréal

Mrs. Graziella Lévy
Pedagogical consultant for elementary science
Commission scolaire Taillon

Mr. Alexander Liutec
Vice-Principal
Chambly County High School

Mr. Marcel Risi
Commercial Director
Centre de recherche industrielle du Québec

Dr. Rocke Robertson (Moderator)
Chairman of the Science and Education Committee
Science Council of Canada

10:45 a.m. Discussion

12:00 noon Wine reception given by the Université de Montréal

12:30 p.m. Lunch

Address: Mr. Pierre Sormany
President
Association des communicateurs scientifiques du Québec

2:00 p.m. Future Directions for Science Teaching in Québec

Dr. Jacques Désautels
Professor
Faculté des sciences de l'éducation
Université Laval

Dr. Graeme Welch
Professor
John Abbott College

Dr. German Gauthier
Vice-President
Education and Research
Université du Québec

Mr. Émilien Girard (Moderator)
Professor
Université du Québec à Trois-Rivières

3:30 p.m. Discussion

4:30 p.m. Concluding Statement

Mr. Gilbert Lannoy
Physics Teacher
Commission scolaire des Milles-Iles

5:00 p.m. Symposium ends

APPENDIX B - SCIENCE TEACHING IN QUÉBEC. WHY? FOR WHOM?

by Mr. Raymond Duchesne, PhD Candidate, Institut d'histoire et de sociopolitique des sciences, Université de Montréal.*

Some Notes on a Symposium on Science Teaching

On 7 March a symposium took place in Montréal organized jointly by the Association des professeurs de sciences du Québec and the Science Council of Canada on the subject of science teaching. In the course of this symposium, science teachers, specialists in the teaching of science and "practising" researchers expressed their opinions on the past and present state of science teaching in Québec, on current problems, (from the primary to the university level) and on the potential course for its future.

Despite the efforts made by the organizers and the majority of the speakers to delineate the problems and the parameters of the discussion, the symposium does not appear to have succeeded in identifying the causes of the malaise presently affecting science teaching in Québec, nor in producing a consensus on desirable solutions. Is the disillusionment with the sciences that has been identified amongst high school students any different, or more profound, than the general disinterest in school? Does the malaise affecting science teaching derive from the fact that students as a general rule benefit little from courses and laboratory sessions or from the increasing scarcity of scientific jobs? Most high school graduates are not only unaware of the main explanations of natural phenomena but, worse still, have an entirely erroneous idea of the nature of science and scientists, their methods and scientific knowledge itself. Who should be blamed - the students, teachers, parents, school boards or the Department of Education? Do we need a radical reform of the programs or should we review

* Mr. Raymond Duchesne is the author of the book La science et le pouvoir au Québec 1920-1965, published by the Éditeur officiel du Québec, 1978 (150 pages).

our methods of teaching? Should we preserve an education that consists essentially of transmitting "scientific truth" or replace it with a system which, by means of epistemological reflection and the teaching of the history of science, brings out the critical character of research and the problematic nature of scientific knowledge? These are only a few of the many questions raised during the symposium for which few solutions were proposed that might have achieved the approval of the majority of the participants.

Several participants nevertheless felt that the question of <u>how</u> science should be taught was of lesser importance than the question of <u>why</u> it should be taught. Rearranging schedules and curricula, revising textbooks, upgrading the image of science and scientists, and even the reform of education practices, however necessary they may be, are meaningful only in terms of the basic objectives assigned by the school to the dissemination of scientific knowledge. Why is science taught in Québec today? The symposium unfortunately did not provide an opportunity to go into this fundamental question; several of the speakers and participants were content to trot out ready-made answers on this point, and evidently regarded these answers as so self-evident and generally accepted that they did not even take the trouble to state them in more than an abbreviated form. By not having gone far enough, the occasion was perhaps missed for examining precisely the nature of the "malaise" affecting science teaching in Québec, especially since the goals of science education continue to be surrounded by the most impenetrable confusion. By critically analyzing the main reasons cited during the symposium as a justification for science teaching, it becomes apparent that none of them are immediately convincing.

The Training of Scientific and Technical Personnel

Science teaching is of course necessary to train the scientific and technical experts that every society needs. As Aristotle observed, until the shuttles of the looms move by themselves, specially trained slaves will be necessary to do the work. As long as scientists, doctors and technicians are necessary for the operation of factories, health services, cultural institutions and the apparatus of government, the primary raison d'être for science teaching will be obvious.

This relationship between the training of scientific and technical personnel and the needs of society in general cannot be established, however, without examining at the same time the relationship between supply and demand. Those who have noted that the number of scientists has been increasing more rapidly than the population as a whole since the seventeenth century take delight in predicting that one day the two curves will come together and all the inhabitants of the planet will be scholars. There is little danger of this happening in Québec, not because the ability to assimilate the more exalted abstractions of science is not equally well distributed here, but primarily because social conditions have a direct impact on the training of new armies of scientists and engineers. The current recession and the stagnation in the growth of the educational system have combined to produce a drop in demand. If there are fewer and fewer undergraduate and graduate students in the laboratories and classrooms of Québec universities, this is not because the professors or their teaching methods are at fault, but rather because the job market for science graduates is poor. A recent study by the Conseil des universités notes that because of excess supply of scientific and technical skills for the demand, there has been a trend over the past few years of declining salaries and working conditions for men and women scientists in Québec.[1]

From this perspective it is no longer sufficient to say we must train researchers, doctors and engineers in order to justify the existence of the faculties, laboratories, professors and budgets. We must be aware of the fact that science teaching and the training of skilled personnel are processes that are subject to general trends in the economic and social system. The crucial point in fact is not to

1. Conseil des universités, Le marché du travail des diplômés universitaire au Québec, Québec, 1980.

know that science teaching is necessary in order to produce and reproduce particular categories of workers, but rather to know how many of these workers should be produced by the school-factory and, since we can afford the luxury of selectivity, who should be admitted to participate in the mysterious rites of science and to membership in that elite of society which comprises scientists. These two questions are eminently "political"; they go far beyond the issue of simple educational reform of secondary and tertiary science teaching in Québec. Until these questions are addressed, the only effect of improvements in curricula, textbooks and facilities is likely to be an increase in the imbalance between the supply of graduates and the capacity of the job market to absorb them.

Education for All?

It would of course be untenable to teach science to all students at the primary and secondary levels merely in order to encourage some of them to follow a scientific career. Mass education must have its own objectives, and specifically must benefit all who receive it. The basic question is therefore to determine why and to what end science should be taught to people who will not embark on a scientific or technical career.

The answer generally given is that a well-designed and well-administered (in the same way that medication or punishment are administered) scientific education makes an important contribution to the training of the mind, especially the rational faculties, and provides the individual with the means to master his or her environment. A much more politically radical variation of this idea was expounded brilliantly during the symposium by Jacques Désautels, Professor at Université Laval. Professor Désautels' thesis was that scientific knowledge is a liberating force; the assimilation of scientific method and content enables individuals and groups to adopt a critical stance with regard to the various forms of power that are also based on knowledge, whether they be the power of the government and its agencies, the power of the employers or of professional bodies whose sole function has become the defence of a monopoly of the right to exercise their profession, and so on. The teaching of science to the greatest number of students is thus justified by the necessity of liberating humanity, and the citizen in our advanced societies, from their servitude to experts of all kinds, a servitude brought upon by ignorance of scientific laws and its processes.

Along with the great idea of the humanistic tradition that the acquisition of knowledge in general and knowledge of nature in particular are inextricable parts of the moral education of the individual and gives one the ability to exercise one's freedom, goes the modern corollary that scientific knowledge is necessary in order to accomplish the great ideas of our times and to understand day-to-day events in postindustrial societies. Tomorrow's citizen and consumer, properly informed about the technical aspects of the problems confronting him or her, will be able to choose and differentiate on the basis of acquired knowledge of what is involved.

Is Scientific Knowledge Liberating?

Is one a better citizen because one can explain the second law of thermodynamics or because one knows how a CANDU reactor works? Are science teachers, engineers, doctors and researchers less subject than their contemporaries to economic market forces, to cultural, racial or class prejudices, to the legitimacy, justified or not, of the authority of the state or any other institution, to the decrees of experts in fields other than their own, and so on? Certainly not! The dissemination by the school system or by popularization of scientific and technical knowledge may be a necessary precondition of liberation, granted, but it is not of itself sufficient. Science can contribute to this kind of liberation only to the extent that it is subordinate to an awareness of the social elements of a problem. The great scientific and technical debates of our times - nuclear energy, water fluoridation, genetic engineering and so on, where there are experts on both sides of the issue - provide a good illustration of the fact that not everything can be reduced to scientific arguments, but rather are directly affected by the concrete situation of the groups involved. However many hours are devoted to curricula, however competent the teachers or the degree to which the new textbooks are "sociologically slanted," science teaching will liberate no one from the "usurped" power of the experts unless it is accompanied by a radical questioning of the social oppression of which this power is merely an instrument and a particular expression. Unless it forms part of an overall plan for a fundamental transformation of society, and despite its claims to be a liberator, the teaching of science in general will continue to have as its principal function the inculcation of respect for science and for the scientist and the preparation of the maximum number of workers for the service of the economic machine.

Science Teachers: A New Professional Body?

It was difficult at the symposium to overlook the exceptional degree of potential interest for science teachers, of certain proposals concerning the reform of curricula and textbooks in Québec and the modesty with which this issue was treated. It is nevertheless beyond question that a reform of science teaching, for which the initiative would come from science teachers, could only benefit them, regardless of the level of the educational system at which they are working. The process of analysis and reform of teaching methods, the preparation of new, specifically Québec textbooks, the increase in the role of science in the curricula, the increase in the number of educational counselors, improvement in equipment - all these aspects would have a direct bearing on an upgrading, both economic and symbolic, of the position of the science teacher within the school system and in society as a whole.

One consideration that is fundamental to the current re-examination of the methods and objectives of science teaching in Québec is undoubtedly the sincere and disinterested desire on the part of teachers to grasp the situation and prepare themselves for changes.

One can also interpret this as the reaction of a particular group of teachers, who have no reason to welcome the continued erosion of the position of the sciences in the curricula and of their own image in the eyes of their audience, the students, their colleagues in other disciplines and the general public. At a time when the educational system is entering a period of retrenchment, if not of recession, the sciences, the "ugly ducklings" among the academic disciplines, are in danger of suffering from cutbacks, in both budgets and staff. The creation of the Association des professeurs de sciences du Québec and the substantial increase in its activities aimed at the public and the government should perhaps be interpreted as signs of a drive for autonomy on the part of science teachers believing themselves to have been poorly served by professional organizations responsible for representing teachers in all disciplines.

It is difficult to decide whether the trade union movement among teachers should be worried about the drive for autonomy on the part of science teachers. This is, however, not the problem that concerns us here, and I mention it only as an invitation to those who are putting their shoulders to the wheel of reform in science teaching to establish very clearly the professional stakes in the measures they are proposing. A reform of this type will find broad support amongst the public only if its foundation and its objectives can be perceived to go beyond narrow professional interests and to be reconcilable with the interests of the broadest possible spectrum of society. The Association des professeurs de sciences du Québec and those who support its actions still have to demonstrate that the reform of science teaching constitutes an element of social progress.

A Spontaneous Philosophy of Science Teachers?

In order to demonstrate that a community of interest exists among those who work at teaching and popularizing scientific and technical knowledge, it is necessary not only to clarify the questions raised above regarding the objectives of science teaching, but also to clear up some of the popular conceptions about modern science and scientific culture. In that these concepts are widespread among science teachers, they could constitute a "spontaneous philosophy" of science teachers.

One of the main elements of this "philosophy," which was cited frequently during the symposium, is the idea that our modern society is essentially scientific and technical in nature. In other words, work, politics, the distribution of wealth and every form of social organization are based ultimately on scientific theorems and their applications. A second idea, which flows directly from the first, is that the culture appropriate to a society of this type is a "scientific and technical culture." As the school system is still one of the principal channels through which culture is disseminated and acquired, it would therefore be entirely legitimate to increase the role assigned to the sciences in the curricula, in order to prepare the students appropriately for a world in which they have an analogous importance.

If we assign to science and modern technology the power to determine how men and women should live and work, think and feel, is this not attributing to them a supernatural power? Is not the assertion that science is simultaneously the foundation and the driving force behind human society evidence of having fallen victim to a cult of scientific and technical knowledge? We would stress that we are not trying to deny the importance of science and technology in the ongoing revolution regarding the means of production and the transformation of the environment, but rather to recognize that modern humanity's dependence on their tools is essentially no different from the relationship between paleolithic people and their flints. What precisely is meant by "scientific culture"? Is it the entire complex of traditional attitudes and customs practised by the tribe of scientists: the "culture" of a specific group which can now be extended to include the advanced societies as a whole? Or do we, using the lowest common denominator, thus designate those fragments of scientific knowledge which the average person (Homo mediocritus) in the advanced societies has been able to assimilate through school, the media or everyday experience? In any event, as the ethos of an elite or as a mass culture, the idea of "scientific culture" is hardly worthy of elevation to the level of the guiding concept for a philosophy of scientific education.

Teachers and popularizers of science are, of course, not the only ones to hold the belief that sometime during the course of their recent history the industrialized societies have undergone a radical transformation, from which they have emerged profoundly different, whether they be called "postindustrial societies," "postmodern societies," "knowledge societies," "postcapitalist societies," "technetronic societies," "planetary societies," or whatever.[2] Nevertheless, by virtue of the position they occupy in the chain of the transmission of knowledge and in the process of the formation of ideas which eventually dominate "popular wisdom," science teachers and popularizers should adopt a more critical stance with regard to this "spontaneous philosophy" of scientific culture. The fact that science teachers are revealed at the same time as both the zealots and the victims of such beliefs constitutes proof enough, should it be needed, that knowledge and academic degrees are not in themselves guarantees against error and alienation.

2. One could complete this list by reading Ralf Dahrendorf et al, Scientific-Technological Revolution: Social Aspects, Sage Publications Ltd, London, 1977.