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Background Study 52

Science Education in Canadian Schools

Volume I
Introduction and Curriculum Analyses

Graham W.F. Orpwood
Jean-Pascal Souque

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Graham W.F. Orpwood

Graham Orpwood studied chemistry at Oxford University where he received bachelor's and master's degrees. In 1966, following a year at the University of London, he began a teaching career that included appointments at a secondary school in England and at the St. Lawrence College of Applied Arts and Technology in Kingston, Ontario. He returned to postgraduate studies in 1975, this time at the Ontario Institute for Studies in Education. He received an MA and a PhD from the University of Toronto, and served as a research officer at OISE for a further two years.

In 1980, Dr. Orpwood was appointed as science adviser at the Science Council, where he has acted as project officer of the Science and Education study. He has coauthored a book, *Seeing Curriculum in a New Light*, and several articles in the field of science education and curriculum theory. His current interests are the methodology of policy research, federal-provincial relations in education and public attitudes to science.

Jean-Pascal Souque

Jean-Pascal Souque obtained his science baccalaureate, master's degree and advanced studies diploma in mineral chemistry from the Université de Paris VI. His work focussed on the analysis of mineral samples by fluorescence of X-rays. After receiving an education degree from Laval University, Mr. Souque taught science education there and pursued research work at the doctorate level on the epistemological obstacles and the nature of science taught in high schools. Holder of a teaching diploma for the province of Québec, Mr. Souque taught chemistry for eight years at the Collège Jésus-Marie in Sillery. He also sat on many advisory committees on scientific training with the Québec Ministry of Education and Télé-Université of the Université du Québec. Since 1981, Mr. Souque has been a project officer with the Science Council. His specialization is in training problems related to science and technology policy.

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Foreword

Excellence in science and technology is essential for Canada's successful participation in the information age. Canada's youth, therefore, must have a science education of the highest possible quality. This was among the main conclusions of the Science Council's recently published report, *Science for Every Student: Educating Canadians for Tomorrow's World.*

Science for Every Student is the product of a comprehensive study of science education in Canadian schools begun by Council in 1980. The research program, designed by Council's Science Education Committee in cooperation with every ministry of education and science teachers' association in Canada, was carried out in each province and territory by some 15 researchers. Interim research reports, discussion papers and workshop proceedings formed the basis for a series of nationwide conferences during which parents and students, teachers and administrators, scientists and engineers, and representatives of business and labour discussed future directions for science education. Results from the conferences were then used to develop the conclusions and recommendations of the final report.

To stimulate continuing discussion leading to concrete changes in Canadian science education, and to provide a factual basis for such discussion, the Science Council is now publishing the results of the research as a background study, *Science Education in Canadian Schools.* Background Study 52 concludes, not with its own recommendations, but with questions for further deliberation.

The background study is in three volumes, coordinated by the study's project officers, Dr. Graham Orpwood and Mr. Jean-Pascal Souque. Volume I, *Introduction and Curriculum Analyses,* describes the philosophy and methodology of the study. Volume I also includes an analysis of science textbooks used in Canadian schools. Volume II, *Statistical Database for Canadian Science Education,* comprises the results of a national survey of science teachers. Volume III, *Case Studies of Science Teaching,* has been prepared by professors John Olson and Thomas Russell of Queen's University, Kingston, Ontario, in collaboration with the project officers and a team of researchers from across Canada. This volume reports eight case studies of science teaching in action in Canadian schools. To retain the anonymity of the teachers who allowed their work to be observed, the names of schools and individuals have been changed throughout this volume.

As with all background studies published by the Science Council, this study represents the views of the authors and not necessarily those of Council.

James M. Gilmour
Director of Research
Science Council of Canada

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This study has been made possible through the cooperation and assistance of so many individuals and organizations that identification of particular ones is difficult, even perhaps inappropriate. Nevertheless, we wish to express our gratitude especially to certain persons. The Science and Education Committee of the Science Council of Canada, under the chairmanship of Dr. Rocke Robertson and Dr. Lawson Drake, has provided valuable encouragement and guidance. Our colleagues on the science education study — Isme Alam, Paul Dufour, Janet Ferguson, Lise Parks and Nancy Weese — have been a constant source of assistance and good advice. And Colleen Gray's editorial hand has resulted in a much improved final product.

Adeline Toussaint, Marshall Nay and Paul Robinson helped while the textbook analysis frameworks were being designed. Dr. Vincent Lunetta kindly encouraged us to use "The Laboratory Structure and Task Analysis Inventory" instrument for our own purposes. The following researchers contributed to the analysis of science textbooks: Garth Benson, Colette Bertrand, Shirley Brauer, Laurier Busque, Bruce Curtis, Roger Fox, Louise Gaudreau, Arthur Geddis, Sharon Haggerty, Charles Hammill, Anne Lamarche, Oliver Lantz, P. Henk Luyten, James Raffan, Karun Raizada, Michael Shiner, Marcel Thouin and Robert G. Whyte. This collaboration is highly appreciated.

Finally, the study could not have taken place without the cooperation both of the Council of Ministers of Education, Canada (CMEC) (and specifically those individuals in each provincial department or ministry of education who have served as liaison persons) and also of the science teaching professionals, especially the science teachers' organizations in each province and territory. To all of these we are indebted.

Part One

Introduction to the Study

I. Focus of the Study

Science forms part of the curriculum of almost every school in Canada. In all provinces and territories, students are required by ministry/department of education policy to study this subject from their earliest years in the classroom until at least grade 9 or 10. In many of these classrooms, special facilities for use in teaching and learning science are provided; in most, textbooks focussed on science are a major component of the students' experience. Correspondingly, teaching science is an important activity for many teachers. For some, it is their specialty; for others, one subject among several that they teach.

But why do students study science at all? For what purposes are all these provisions made? For what objectives are the textbooks and classroom activities designed? What educational aims are in the minds of those who teach? Furthermore, are these various intentions, purposes, and aims congruent? Are the aims of science education set forth in ministry/department policies reflected in the objectives of teachers, textbooks, and classroom activities? And, most important of all, do all (or any) of these objectives reflect the needs of students in school, who are living and growing as individuals, as members of society and as participants in the Canadian economy, now, to the turn of the century and beyond?

Why is science taught? Although this might seem a trivial question, it is important not just to assure oneself that there are answers — that science is a defensible part of what students are offered — but because the nature of the answer(s) affects what one expects of science education. And, in asking about the aims of science education, we are asking about the health of the enterprise itself and about its relation to the social context. The relationships among the stated aims of science education, the concrete realities of science in schools and the future needs of Canadians are recurrent themes in this study of science education in elementary and secondary schools.

While this background study is bound, for convenience, in three volumes, it is not a series of independent studies. The research program of the overall study consists of a group of interrelated components, all of which are set in the larger context of an overall strategy called a "deliberative inquiry." To assist the reader in appreciating this strategy and the relationships among its various components, part one of this volume contains discussions of the objectives and focus of the study (chapter I), of the overall strategy of deliberative inquiry (chapter II) and of the research program conducted (chapter III). Parts two and three describe in detail analyses of provincial curriculum policies for science and of science textbooks. Volume II contains reports of a survey of science teachers and volume III, case studies of science teaching.

Criticisms of Science Education

In October 1979, the Science Council decided to undertake a study of science education in response to various criticisms that had begun to surface during the previous few years. Criticism of education is nothing new; the school curriculum is a perennial target for critical comment from inside and outside the school system. But, from time to time, criticisms of a particular type come together to generate an especially strong challenge for change. The history of education contains many examples. In the case of science education, the post-Sputnik move towards a greater emphasis on teaching about the nature of science is one such instance. But the present round of criticism is quite different. At issue now is not that students are not learning what science is, nor that they are failing to learn enough of it (although these are both of continuing concern to some critics), but rather that students do not come to appreciate the personal, social or national relevance of science.

A significant influence on the Science Council's decision to conduct the study was Professor Thomas Symons. He observed in the report of the Commission on Canadian Studies:

> "Canadian school children learn of the accomplishments and impact of science in other countries. . . but they learn virtually nothing about the impact of science in their own country. And the reason is that they are not being taught such matters."[1]

Symons was, of course, concerned that science was not being identified for students as part of the "cultural fabric of society."[2] Rather, it was being presented as a body of knowledge and technique, divorced from any national context of practice and application including its historical development in and social implications for the Canadian community. Such a criticism is puzzling, even offensive, to many who are trained in science and who take particular pride in the universality of their discipline. This reaction is a matter to which we shall return.

David Suzuki, himself a member of the Science Council of Canada, is another prominent critic of Canadian science education. He has often suggested that by perpetuating the separation of the two cultures (arts and science), schools "fail to educate."[3] Such an education, he claims, serves neither the country's future scientists nor the general public and their political leaders.[4] On the one hand, potential scientists are not taught that they have a moral responsibility to society, while, on the other, members of the public, even the highly educated public, are shamelessly ignorant about the effects of science and technology on their lives.

While these criticisms were directed towards science education throughout Canada, more specific concerns were also surfacing in some provinces, where more intensive research into the state of science teaching had been conducted. In Québec, for example, Jacques Désautels, in *École + Science = Échec* (School + Science = Failure), strongly challenged current ways of teaching science. He warned:

> "Research results show that students are not developing scientific attitudes. Their interest in science is decreasing instead of increasing. Still worse, because of 'streaming' in schools, science teaching promotes elitism rather than scientific literacy. Not only do our students fail to learn anything; they are miseducated."[5]

Thus, both at the national and at the provincial level, concerns were being expressed about the state of science education in schools.

The Science Council did not accept these criticisms without question. Nevertheless, coming from well-placed observers of the educational system, they were cause for concern. If the assertions were correct, the consequences for Canada and Canadians were serious. In a society increasingly dependent upon science and technology, a public with little or no understanding of science and its impact on society is at the mercy of technological change. Recognizing the seriousness of these criticisms, the Science Council of Canada concluded that the establishment of a study on science education in Canada could be justified as important to the scientific health of the nation and thus as falling within its responsibilities.

Concern over the state of science education is not a uniquely Canadian phenomenon. In the past several years, reviews of science education have been conducted in the United States[6] and in England.[7] And, in the developing countries, the need for revitalizing scientific and technological education is so great that UNESCO recently sponsored a special conference on the subject.[8] Thus, the Science Council's study can be seen as parallel to other national responses to similar concerns about the teaching of science in schools.

Objectives of the Study

The criticisms and concerns have been articulated with sometimes disarming clarity and force. However, it does not follow that a problem amenable to research and policy analysis is equally clearly discernible.[9]

While all the critics agree that science education in Canada needs improvement, they do not observe the same symptoms, diagnose the same ailment or prescribe the same remedy. Suzuki's concern for the lack of a sense of moral responsibility among science specialists would not be affected by Symons's suggestions for greater attention to Canadian science. Nor would Désautels's preferred curriculum solve the problem of inadequately trained human resources for high technology industry, identified by others. It is difficult, therefore, to identify a research problem directly based on these comments without implicitly backing the position of one critic over the others and thus, to some degree at least, anticipating the conclusions of the study.

However, the apparent confusion can be resolved into a series of arguments over the ways students are taught science and the purposes for which students learn science. The critics are arguing that science education is not being directed towards what they regard as the most important objectives or, at least, that science education is not achieving the objectives it claims to be achieving. And, for the most part, they are basing their arguments on assessments of the present or future needs of students. This type of criticism is quite distinct from concern over the content of science education. For example, we have not been hearing in recent years that students should learn more (or less) about, say, magnetism or genetics, but that such topics should be learned so that students come to recognize the social and personal relevance of scientific knowledge.

Based on this interpretation of the thrust of the major critics of science education in Canada, the study was established in the spring of 1980 with three general aims:

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

The first of these aims arises from the need to have a factual basis for debating criticisms of the variety discussed earlier. Since Canadian science education generally lacked such a basis, the research reported in this background study was conducted to meet this need. At the time of writing, work on the second aim is still in progress. The historical perspective enables one to understand present practice (including the objectives of the enterprise) in the light of past experience. Very little effort has been made in the past to collect or analyze the historical background of science education in Canada. The third and most important aim follows from the first two. If change is not only to be justified logically but also to be implemented practically, then those responsible for science education in Canada must themselves deliberate over their purposes and practices. Work towards this aim consists of stimulating a process rather than developing a product and will be discussed in more detail in chapter II. For the present, the concept of "purposes of science teaching" must be clarified and linked to concrete targets of research.

Conceptual Basis of the Study's Objectives

Two pieces of theoretical work have been particularly useful in clarifying what we mean by "purposes, aims, or objectives in science teaching," and how we have tried to identify them in practice: Roberts's concept of a "curriculum emphasis,"[10] and Argyris and Schön's analysis of different "theories of action."[11] In this section, we explain these two conceptual components of the study and use them to clarify the relationships among the aims of science education, the practice of science teaching in schools, and the needs of students. The third conceptual component, educational "needs," is more difficult to explore. "Needs" adds a normative or ethical component which changes the nature of the overall problem. It is the key to understanding the methodology of the study and will be discussed in detail in chapter II.

Curriculum Emphases: Expressing Educational Aims through Teaching

The teaching of science, like most other forms of communication, conveys more than one set of messages to its recipients simultaneously. At one level, science teaching communicates scientific information. But, beyond this level of communication, science content is always embedded in a contextual web of intent or purpose. The various contexts in which science topics can be presented can result in correspondingly different learnings on the part of the student. These different "contexts" have been described by Roberts as "curriculum emphases." He explains this term as follows:

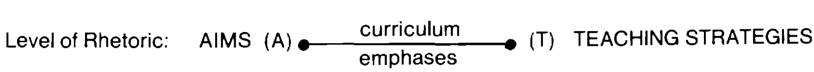
> "A curriculum emphasis in science education is a coherent set of messages to the student *about* science (rather than *within* science). Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself — objectives which provide answers to the student question: 'Why am I learning this?' "[12]

And, while part of any science educator's concern is for teaching the content of science to students, another — frequently an even more important part — is that the content be learned for some purpose beyond itself.

The example of separate treatments of the same science topic in two different grade 8 textbooks illustrates the point. In one textbook, all of the information about the methods of heat transfer (conduction, convection and radiation) is set in a context of explanations about how refrigerators and solar heaters work. Photographs and "cut-away" diagrams illustrate these explanations. In the other, the same scientific principles are discussed but, this time, accompanied by an historical comparison of different (and competing) theories to explain thermal phenomena. This account is illustrated with excerpts from 18th-century scientific reports. In each case, the science content being communicated is the same while the contextual communication — the curriculum emphasis — is markedly different. And these different emphases are the concrete representations of each book's different purposes for a student's learning of science.

Considerable research in recent years has shown the "curriculum emphasis" concept to be useful, not only for analyzing textbooks, but also for understanding curriculum policy debate,[13] for developing instructional units[14] and for interpreting different strategies of classroom teaching.[15] In the present context, it provides a conceptual link between two key components of the study, the aims or purposes for science education and the teaching strategies through which those aims are realized in practice. This relationship (see Figure I.1) appears simple when viewed abstractly. However, when one examines, as the study has had to do, both the rhetoric* and the practice of science education, its complexity intensifies. For clarification of this conceptual component of the research, we turn to the analysis of Argyris and Schön, whose concern is with how individual professionals think and work within institutional contexts.

Figure I.1 – The Link Between Aims and Teaching Strategies



Theories of Action: Teaching and Talking about Teaching

Relating theory to practice in education — as in most other professional fields — has been a traditionally controversial and seemingly intractable problem. This is not the place to review the variety of attempts at resolving it and the corresponding variety of consequences for research

*Note that "rhetoric" is being used here in its root sense of "language designed to persuade or impress" and not in its more usual, modern sense implying insincerity or emptiness.

and professional education. The "curriculum emphasis" concept helps one to understand the relationship between the aims of science education and the strategies teachers use in classrooms. But one must also realize that this concept can apply to education in more than one way.

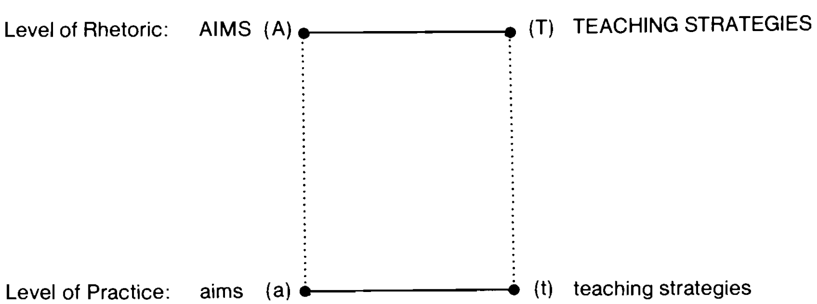
Argyris and Schön, whose work has focussed on the problems of increasing professional competence within organizations, have developed the notion that individuals' behaviours are determined on the basis of personal "theories of action."[16] Such theories are about how to produce intended consequences and thus about human effectiveness.[17] Everyone has a "theory of action" for their deliberate activities, whether or not they have articulated these theories. However, Argyris and Schön point out that people do not necessarily behave congruently with their stated theories of action.

> "When someone is asked how he would behave under certain circumstances, the answer he usually gives is his espoused theory of action for that situation. This is the theory of action to which he gives allegiance and which, upon request, he communicates to others. However, the theory that actually governs his action is his theory-in-use, which may or may not be compatible with his espoused theory; furthermore, the individual may or may not be aware of the incompatibility of the two theories."[18]

Argyris and Schön assert that "although people do not behave congruently with their espoused theories,. . . they do behave congruently with their theories-in-use, and they are unaware of this fact."[19] According to this notion, all professional practitioners, such as doctors, teachers and research scientists, have two sets of theories relating to the various parts of their professional practice. Such an idea is not, of course, a revolutionary one; the gap between practice and theory, between concrete events and the rhetoric concerning them, is well documented in several professional fields. Argyris and Schön's contributions are, firstly, in generalizing the idea and, secondly, in developing proposals for professional improvement on the basis of this idea.

Following Argyris and Schön, our research program addresses two levels of reality (Figure I.2). One level corresponds to the "espoused theories" of educators, described here as the "level of rhetoric." At this level, talk about teaching or about educational aims takes place. Policy statements from ministries/departments of education such as curriculum guidelines, prefaces to textbooks and teachers' talk about the aims and techniques of science teaching all function, by definition, at this level. The second level, the "level of practice," corresponds to teachers' "theories-in-use" and represents the level of educational reality at which science classrooms function. The ways in which teachers actually teach, the real content of textbooks, and the concrete activities in which students participate are all at this level. It must be stressed that recognition of these two levels of reality implies no pejorative attitude towards activity at either level. Practice is not necessarily worse because it does not correspond to rhetoric nor is talk about practice necessarily futile because its outcome cannot be translated directly into action. However, research into science education must be planned to take into account the existence of these two levels (and the inevitable discrepancies between them). Only through such planning can research be expected to increase the common understanding — common, that is, both to practitioners and observers or critics — of science education in Canada.

Figure I.2 – Two Levels of Reality for Educational Research



Scope of the Study

Certain practical limits to the scope of the study were established at the outset. Two, in particular, deserve mention: the levels of education at which the teaching of science was examined; and the definition of "science" stipulated by the study.

Educational Levels

The study is primarily concerned with the teaching of science at the pre-college levels only. The main reason relates to the objectives of the study, which are focussed on the purposes or aims of science education. As students grow and move through the educational system (from kindergarten on, even perhaps to graduate school) their reasons or purposes for studying science change and so, correspondingly, do those of the programs and courses. At the highest levels, where students intend to specialize in scientific work for a career, program objectives are relatively few and specific (even if they are not well articulated). By contrast, at the elementary and secondary levels, the numerous and broad objectives correspond to the much broader range of students. At these levels, schools must attend to the needs of all students and science programs must therefore serve a wide variety of purposes. And it is to science education at these levels that the criticisms considered earlier have been directed.

The selection of science education in elementary and secondary schools as the study's major focus does not, of course, preclude consideration of other related activities which impinge on school science: university or college-level science education, science writing, broadcasting and films, museums and science centres, and any activity, organization, publication or event that can have an impact on the teaching or learning of science in school.

Table I.1 – Distribution of Grades by Province

Province/Territory	Early Years	Middle Years	Senior Years
Newfoundland	K-6	7-9	10-11[a]
Prince Edward Island	1-6	7-9	10-12
Nova Scotia	K-6	7-9	10-12
New Brunswick	1-6	7-9	10-12
Québec	K-6	7-9	10-11
Ontario	K-6	7-10	11-13
Manitoba	K-6	7-9	10-12
Saskatchewan	K-6	7-9	10-12
Alberta	K-6	7-9	10-12
British Columbia	K-7	8-10	11-12
Northwest Territories	K-6	7-9	10-12
Yukon	K-7	8-10	11-12

[a] At the time of data collection, Newfoundland had not yet implemented its grade 12 program.

Within the years of elementary and secondary schooling, each province and territory groups its grades into levels for curriculum purposes. Following this practice, we decided to refer to three clusters of grades as "early years," "middle years" and "senior years" within each jurisdiction. However, provinces group their grades in various ways. We therefore followed the grouping of grades encountered in each province rather than imposing a uniform distribution. Table I.1 shows the three levels used throughout the study with the corresponding grades.

"Science" in Schools

The stipulation of what is regarded as "science" in the context of this study has been controversial because it is necessarily arbitrary. The controversy was not readily resolved by using a formal definition of science to distinguish among school programs. Lists of school programs often have administrative rather than philosophical significance. Yet school people know what they mean when they talk of "science" programs as distinct from other school program areas. And since the school science curriculum is the focus of the study, such school convention has also appeared to be the best basis for a stipulated definition of "science." The study has therefore examined those areas of the school curriculum designated in each province and territory as "science."

Concretely, this has meant that physical, biological and earth sciences have been included and mathematics and social studies have been excluded from the major focus of the study. However, the effect of these latter subjects on the teaching and learning of science has also been considered. This leaves a number of subjects, such as computer studies, agriculture and technology in a poorly defined "grey area." In provinces where these subjects are considered to be science subjects, they have been included.

II. Deliberative Inquiry

Overview of the Strategy

In this study, we take the position that discussions concerned with changing the school curriculum inevitably possess both a rational and a political character. While much of what follows in this three-volume background study is an account of apparently conventional research, the rational/political character of the context in which it was conducted is crucial to understanding its significance. It is thus worthwhile to explain the position in some detail in order to clarify the study's overall strategy whose very name, deliberative inquiry, is intended to convey its eclectic nature. There are essentially three grounds upon which this position rests.

Science Curricula as Policies

That a study focussed on the teaching of science in Canadian schools has both a rational and a political character derives, first, from the view that the school curriculum is itself a form of policy. This is not the conventional view. The traditional view sees the process of curriculum change as being highly rational and frequently linear. Aims are first identified, sometimes on the basis of so-called needs assessments; then instructional strategies are developed as the means of reaching those aims. One of us has argued at length elsewhere[1] that such a view is inadequate. Curricula should not be regarded as though they were mere artifacts, things that can be made. If that were the case, the rational planning models might indeed be appropriate. However, a curriculum decision represents more than just a rational conclusion to include topic X or method Y in a curriculum document. It represents a commitment on the part of an individual or a group to act in a specific manner in a given context (defined in terms of both time and place). And that is a political judgement as well as a rational one.

An example may clarify the point. Suppose the coordinator of science for a school board has made the decision to include in the grade 7 science program for the board a unit on energy to be taught with a curriculum emphasis on its social relevance. And suppose, also, that this decision has been endorsed by the director of education; it then becomes part of the board's official program, which teachers of grade 7 science in that jurisdiction are required to teach. The decision is, or should be, a rational one — the coordinator should be able to defend it with reasons, presumably based on students' prior knowledge, their future needs, the topic's place in the discipline, the social context of education and so on. But the decision also has political impact; it requires people (mostly teachers) to act in certain ways — to teach energy with the approved emphasis — when placed in specific circumstances: this board, this grade, this year and so on. If the decision-making process has failed to take into account this duality of character, the chances of effecting a defensible change are small. If the coordinator acts only in a rational manner and fails to consider the impact of the new requirement on the teachers involved, the decision, however defensible in principle, will likely be resented and very possibly not implemented. If, by contrast, the coordinator acts in a purely political manner and disregards the substantive merits of the decision, he has failed to live up to a professional responsibility to seek ways of improving the board's science program.

Curricula are therefore regarded as a type of policy[2] involving rules, plans or guides for the determination of what shall be taught in specific situations. They are therefore distinct from curriculum resources such as textbooks that are developed for general and voluntary use. A curriculum is both a product of reason and a commitment of will. It has political force as well as rational content. A study of science curricula in Canadian schools must take this duality into account, particularly if that study seeks to recommend changes to those curricula.

Needs Assessment and Discovery of Aims

It is sometimes suggested that the key to curriculum planning is to begin with a systematic empirical assessment of what students ought to learn.[3] Indeed, we have acknowledged that arguments about what ought to be taught in science classes and criticisms of what is taught are usually based on assumptions concerning the needs of students either now or in the future. But the future is by no means clear. And the problem is that both children and the society in which they live have a bewildering variety of what can be called needs, each suggesting a different direction for the curriculum. As Len Berk points out:

> "We have no standard procedure for resolving disputes over who needs how much of what. In fact, the individual needs that can, in principle, be met through schooling can also, in principle, be obviated by altering some feature of our public life. . . . Because we

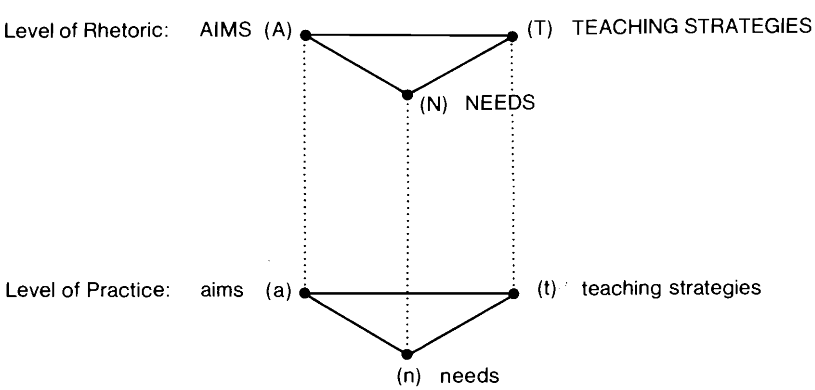
cannot assume our public life is beyond question, any attempt to determine what students need is liable to be contentious."[4]

Berk refers to an earlier wave of enthusiasm in the United States for "scientific curriculum-making," as it was actually called in the 1920s. His conclusion is disarmingly clear:

> "As a procedure resembling inquiry more than deliberation, needs assessment seems to supply a dodge in the face of disagreement; it would permit us to discover the aims of schooling instead of our having to decide them. Franklin Bobbitt also hoped to discover the aims of schooling and was, properly, roasted for it. Then as now deliberation about aims seemed risky, unmanageable, and subject to contamination by politics. So it is. Discovery of aims (or of the needs that produce them) seemed systematic, authoritative, and politically antiseptic. This is a delusion."[5]

While educational needs and the corresponding aims or objectives are important for the assessment or determination of science curricula at the levels of both rhetoric and practice (see Figure II.1), they cannot be discovered from the research literature. They must be deliberated over and, in a democratic society, all who have a stake in the outcome have the right to participate in such deliberations.

Figure II.1 – Educational Aims, Teaching Strategies, and the Needs of Students



Stakeholders in the Science Curriculum

The proponents of empirical research as the means of determining the curriculum assume that there is in reality a social consensus on the goals of education and that the problem lies in uncovering that consensus. By contrast, in this study we view society as containing value conflicts over educational goals and regard the problem as one of consensus-building.[6]

Talk of value conflicts implies the existence of interest groups and consensus-building among different interest groups in society implies a process of political deliberation. Of course, the specifics of the curriculum are not often the focus of formal political debate nor do they usually form planks in political platforms at election time. However, the needs of students in school, the orientation of the school curriculum and the concrete activities of the classroom can be regarded as the product of reasoned debate among definite and distinct interest groups.

Time has not altered this process, as a reading of Aristotle's *Politics* shows. As he cites what we would call the school curriculum as a paradigm of a political problem, he writes:

> "As things are, there is disagreement about the subjects. For mankind are by no means agreed about the things to be taught. . . . The existing practice is perplexing, no one knows on what principle we should proceed – should the useful in life, or should virtue, or should higher knowledge be the aim of our training, all three options have been entertained."[7]

The contemporary relevance of the nature of the controversies is striking. Yet, as we have noted already, such a political view of the curriculum has not been common in the literature.

In a recent article, Connelly and his colleagues suggested that the concept of "stakeholders" can help in explaining the roles of the many individuals and groups who hold views about the school curriculum and desire to influence curriculum decisions correspondingly.[8] As they point out, everyone has some stake in the school curriculum.

> "This claim may be direct and immediate, or it may be tenuous or obscure — but it is always there, whether strident or passively silent. The school is the creature of society, shaping it and being shaped by it, reflecting its characteristics and responding to its needs, and in so doing, it — and the teacher — cannot disregard the stakeholders."[9]

Students, teachers, parents, school trustees, the scientific community, industry, the labour movement and many other groups and institutions all hold stakes in the science curriculum. The critics of science education whose comments were outlined earlier are all stakeholders and their stakes are as different as their backgrounds and viewpoints. In recognizing a variety of stakeholders in the science curriculum, we are not necessarily imputing to such individuals or groups any improper motivation or intent to subvert the schools to their own purposes. We merely recognize a reality whose existence must be of key importance in planning a study on science education in Canadian schools.

A study in which many stakes in the science curriculum are seen as legitimate is likely to have a significantly different outcome than one dominated by one or a narrow group of stakeholders. For example, in the post-Sputnik era, the science curriculum (especially in the US) changed — at least at the level of rhetoric — from an emphasis on the domestic and industrial application of science (dominant in the curricula of the 1940s and 1950s) to a more abstract and intellectually sophisticated emphasis on the nature of science, its structure and processes. It was no coincidence that this reorientation was influenced by scientists in the academic community and funded (in the US at least) by the National Science Foundation. Current concerns over the lack of relevance of such curricula to society and to students' own experience of life are demonstrating the effect of allowing one group of stakeholders to have an overriding voice in determining the curriculum.

The strong commitment of individual stakeholders to certain curriculum emphases often results in their viewing other emphases (equally strongly promoted by other stakeholders) as distractions, as watering down the curriculum or as downright misleading. The resistance of some members of the scientific community to Symons's suggestions that science be placed in a Canadian context is a case in point. Decision makers must weigh the conflicting advice and ask who are the relevant stakeholders and what are their stakes. If these questions are not attended to, the future direction of science education in Canada can be determined by the loudest shout or the most devious political manoeuvre. However, if the questions can be answered, then the issues can be settled deliberatively with regard to the reasons for action.[10] The process should therefore be both political and rational.

Internal and External Stakeholders

Not all stakeholders are equal, however. The "internal stakeholders" are politically or professionally accountable for the choices made in science education. They are ministers of education and school trustees who have political responsibility and accountability and their officials, administrators and teachers, who are accountable by virtue of their employment in ministries or school systems. All others are, by definition, "external stakeholders" — university professors, persons in business and industry, members of the public, parents and of course the Science Council of Canada itself. They have stakes in the curriculum but are not politically or professionally accountable for it. This combination of having a stake in education and freedom from accountability gives them the privilege of criticizing the work of education — and many do, often and vigorously. However, if external stakeholders are to contribute to the improvement of education, they must observe and accept certain ethical principles* governing their relationship to the internal stakeholders.[11] A specific instance of this relationship appears below.

During the course of the study, comments were made concerning the propriety of a federally chartered and funded agency such as the Science Council of Canada being involved in a study of science education in elementary and secondary schools, clearly an area of provincial

* These principles will be discussed in the context of their application in the specific and different parts of the study.

jurisdiction. The Science Council recognizes provincial authorities as internal and itself as external to the system of science education, but argues that its mandate gives it an unquestionable stake in the enterprise. Moreover, the Council of Ministers of Education, Canada (CMEC), in a formal vote at its meeting in September 1980, approved cooperation with the Science Council in the study, subject to certain conditions concerning the scope and day-to-day conduct of the study.

Finally, what of the Science Council of Canada's own stake in science education? Since it has never declared itself on the subject in its past reports, no "position" can be assumed in advance. Indeed, the study can be regarded as the means by which the Science Council has determined the nature of its stake in the educational system. Its final report of the present study is the statement from which its stake can be inferred.* During the course of the study, Council has been concerned to listen to others, to conduct its own research, and to facilitate deliberations among a wide variety of stakeholders.

Details of the Strategy

The third aim of the study, "to stimulate active deliberation concerning future options for science education in Canada," is the major one because both of the other aims are intended to contribute to its achievement. The following outlines the means by which this goal has been reached.

The name "deliberative inquiry" is intended to convey the idea of two processes taking place in an integrated and mutually informing manner throughout the study: inquiry into the present (and past) objectives and methods of science education in schools, and deliberation over future directions in the field. Considered from another perspective, these two processes each embody, though to differing extents, the rational and political characteristics essential to a study focussed on the school curriculum. Indeed, it is possible at various stages of the study to understand its activities in terms of their rational and political functions.

To accomplish the aims of the study, deliberative inquiry must generate three components:

- a continuing commitment to deliberation and possible change on the part of all stakeholders in Canadian science education, particularly on the part of insiders;
- a reliable database about the context in which any proposed change in science education must take place;
- a range of issues and alternative courses of action to form the substance of deliberation.

Since these components are interrelated, all three required simultaneous attention. However, at any given time, one component occupied centre

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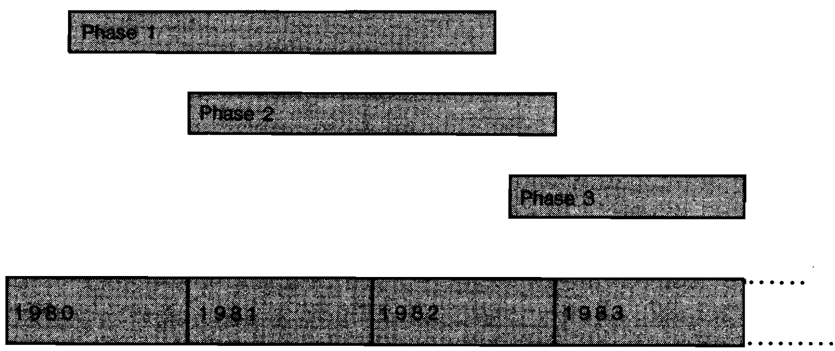
* See Report 36, *Science for Every Student: Educating Canadians for Tomorrow's World*, Science Council of Canada, Ottawa, 1984.

stage. The study's progress comprised three overlapping phases, lasting for some three and one half years (see Figure II.2).

1. Issue identification (May 1980 to August 1982)
2. Data collection (January 1981 to December 1982)
3. Problem resolution (September 1982 to December 1983)

The following summary of the study's activities makes clear how each phase contributes to each of the three components.

Figure II.2 – Schedule of the Study



Phase 1: What are the problems?

James Page's discussion paper, *A Canadian Context for Science Education,* marked the beginning of the first phase, issue identification. This paper was the first of a series of discussion papers, in which authors, from their various perspectives as individual stakeholders, offered their particular critical but constructive commentary on science education.[12] Each paper can be analyzed according to the view of the educated person its author portrays and therefore according to what the author perceived to be the learner's needs and the desirable aims for science education (see Table II.1 for our interpretation of the papers based on this analysis). From their various perspectives, the authors criticized existing practices of science education and suggested alternatives.

Some issues were more amenable to identification through workshops than through discussion papers. The Science and Education Committee sponsored three workshops and published their proceedings.[13] These papers and workshop proceedings were disseminated free of charge to all who requested them. The study has also encouraged discussion by teachers, policymakers and other insiders. Supporting the publications were bulletins sent out to a large mailing list of interested individuals and speaking engagements undertaken by project staff throughout the country. A number of media interviews, magazine articles and reviews in professional journals helped to bring the study's themes to the attention of the science education profession.

These forms of communication, especially the publications, from which the others are derived, served three purposes. They stimulated the insiders' awareness of criticisms of their enterprise and of the need for them to participate in deliberations over future directions. The task of stimulating deliberation was time-consuming and arduous, especially in a country with the geographical, political and linguistic character of Canada. However, science educators in all provinces and territories received the communications and were actively involved in all aspects of

Table II.1 – Summary of Positions Expressed by Discussion Papers

	Positions Expressed		
Author/Title	Selected Features of the Educated Person	Needs of Learners and Implied Aims for Science Education	Critique of Present Practice
James Page, *A Canadian Context for Science Education*	A Canadian citizen, aware of his/her cultural heritage	To understand science as a part of the cultural fabric of Canada	Lack of a Canadian context in science education
Glen Aikenhead, *Science in Social Issues: Implications for Teaching*	A person capable of participating in and understanding social and political decisions	To understand science as one way of knowing among many	Science taught as all- and self-sufficient
Donald George, *An Engineer's View of Science Education*	A solver of practical problems	To develop skills such as those of the engineer	Only the skills of the scientist taught
Hugh Munby, *What is Scientific Thinking?*	An independent thinker	To understand the basis for one's knowledge	Teaching encourages intellectual dependence
Marcel Risi, *Macroscole: A Holistic Approach to Science*	A creative contributor to industry and society	To develop a sceptical, divergent, questioning and imaginative approach towards problem situations	Science taught only as a body of knowledge
Douglas Roberts, *Scientific Literacy: Towards Balance in Setting Goals for School Science Programs*	A scientifically literate individual	To reach a broad spectrum of goals through science education	An imbalance of aims

the study. This political function also had a rational component in that debate and argument were undertaken wherever the papers were studied, and particularly in faculties of education. Out of these discussions has developed a keener sense of some of the problems of science education in Canadian schools, as viewed by both internal and external stakeholders.

The discussion papers and workshops also contributed substantive themes for the data-collection phase and furnished ideas about new directions for the final deliberative phase of the study.

Phase 2: What are the facts?

As mentioned earlier, critics of science education (including the authors of discussion papers) have frequently made claims about the existing state of science education, for which there is no factual basis. Clearly, the study needed to establish such a basis, if for no other reason than to validate or invalidate these claims.

But beyond this need, deliberation over future directions also required a database about the present aims and practices of science education. And the second phase of the study, the research or data-collection phase, developed such a base. Not all types of empirical research on science education are necessarily of value in building this database, however. This research effort is not theory-oriented since its ultimate goal is not that of acquiring knowledge but of informing the process of deliberation. Action-oriented research is a less well understood or developed art (see chapter III for more details).

One of the constraints on research by outsiders such as the Science Council in areas of insiders' responsibility is the need for both researchers and practitioners to work cooperatively. The Science Council and the CMEC agreed upon general conditions at the outset. Both the ministers and the CMEC secretariat were represented by observers at meetings of the Science and Education Committee to advise on overall directions of the study and to act as an official channel of communication between the Committee and the CMEC. Furthermore, we did not conduct research within any province without first consulting the corresponding ministry/department of education. Finally, we sent copies of all reports to ministries/departments of education sufficiently in advance of publication to allow for comments and criticisms.

No doubt, some will regard such negotiation and consultation negatively, as threats to the independence and validity of the research. However, we view the matter differently — insiders such as ministries and teachers can contribute to the research and by doing so increase its validity and their commitment to its results. The dual nature of the study is again evident, where even this most rational of the study's activities has its political aspect.

Phase 3: Where do we go from here?

In deliberative inquiry, conclusions are not deduced from theory nor induced from experience. They are deliberated over using both research data and value positions. As Schwab outlines:

> "Deliberation is complex and arduous. . . . It must generate alternative solutions. . . . It must then weigh the alternatives and their costs and consequences against one another, and choose, not the *right* alternative, for there is no such thing, but the *best* one."[14]

Deliberations are limited to developing solutions that are the "best" (under the circumstances) because those solutions have to be implemented in real schools by real teachers. Sometimes, programs for educational reform are developed on the basis of an ideal, what might be if one could build a school system from scratch. However, rarely, if ever, is one building from scratch without constraints. Implementing such programs sometimes distorts them beyond recognition.

The Science Council's study is concerned with science education in the schools that we have now and with how these can be improved, not replaced. Whether or not a program can be feasibly implemented must therefore be a constraint on the deliberative process. This is one of the reasons why deliberative conferences were held separately, in each province and territory, during the third phase of the study. In each of these jurisdictions, invitational conferences included a cross-section of stakeholders, both insiders and outsiders, to debate, in the light of the Council's publications and research, the future needs and opportunities for science education.

While specific agendas for each conference were developed locally, all of them had three general objectives:

- to review (a) the themes of the Science Council's study as set out in published discussion papers and workshop proceedings and (b) the research data developed by the study, as these were relevant to the province;
- to identify desirable new directions for science education in the province together with structural and other changes required to implement these new directions;
- to develop suggestions for consideration by the Science Council of Canada's Committee on Science and Education for the preparation of their final report.

Again, in this final phase, the rational and political character of the process is evident. While the deliberations attended to the reasons for action, their broad representativeness (in terms of the array of stakeholders) enhanced the political credibility of the outcome. For while rationally argued-for solutions may be convincing intellectually, they must also be politically acceptable if change is to take place. In summary, three ingredients are essential for successful deliberations.

1. People committed to finding or at least searching for solutions to problems confronting science education. These must include

insiders, those responsible for and professionally engaged in science education, as well as an array of outsiders, those with a stake in but no responsibility for the enterprise.

2. Information about the enterprise at hand, and about its aims and teaching strategies in particular. This three-volume background study contains a major part of this information; however, participants in deliberation each have a personal base of equally valuable information.
3. A set of issues and options for future action is the third and key ingredient for deliberation. Again these are of two types: the themes raised by the study through discussion papers and workshops; and local issues of particular importance and concern.

No deliberative process can be precisely mapped in advance. And while the Science Council's role in the process is necessarily limited both in scope and duration, the deliberations themselves need not be so constrained. When the formal activities of the study are completed, it is hoped and intended that the momentum of deliberations in each province will be such that they continue.

III. Research for Policy Deliberation

Deliberations concerning the future orientation of science education clearly need to be grounded in a firm base of knowledge about its present state. However, what is less easily determined in advance is the specific information required for such a process and thus the type of research program which should be mounted in the context of a deliberative inquiry such as the present study. To some extent, the answers to these questions have been anticipated in the first two chapters where, first, the focus and, second, the overall strategy of the study have been discussed. Two major features of the study from these earlier discussions (the focus on aims of science education and the purpose of informing deliberation) are reviewed briefly here to set the stage for the rationale and overview of the research program which follow.

Figure I.2 (see p. 28) represents science education as the interplay of four elements — the aims of science education and the corresponding teaching strategies, as these two function in both the rhetoric and practice of science teaching. These elements are designated for convenience A,T,a,t. The "curriculum emphasis" concept has been described as the means by which aims can be combined with science subject matter in curriculum materials and instruction (A—T) or by which curricular aims or intentions can be inferred from observations of curriculum materials and instruction (t—a). The relation between the levels of rhetoric and practice (A—a; T—t) is more problematic as research concerning how teachers translate curricula into practice or theorize about their own experience is still relatively new. This study may shed some light on this important problem area, although that theoretical goal is not, of course, its primary one.

The major purpose of this research program, as set out in the study's three overall objectives and discussed in the previous chapter, is informing the deliberative process about the context of any changes being contemplated. For this reason, it is important that information be collected, not just about the four elements described earlier which are of central interest to the study, but also about the broader contexts in which these elements are set. Five such contexts can be identified as being particularly important in this regard:

1. policy context (curriculum guidelines, textbook authorizations, teacher certification, etc.);
2. professional context (backgrounds, qualifications and experience of teachers, etc.);
3. instructional context (textbooks and other instructional resources; also students, their abilities and interests, etc.);
4. institutional context (physical facilities, scheduling, class size, etc.);
5. social context (attitudes of peers, school principals, parents, school trustees, industry, universities, etc.).

These contextual factors are identified here to indicate the range of matters about which information is required for deliberations where changes in aims or teaching strategies are being contemplated.

The goal of this research — informing the deliberative process — is sufficiently distinct from that of most science education research that some reflection on the range of research strategies available and on their relative appropriateness is warranted in order to justify our particular choice of a research program.

Explanatory Research and Practical Research

Research for deliberation is not necessarily equivalent to science education research in general. Certain forms or techniques of research may be more appropriate than others. Although all research is directed towards the generation of knowledge, it is necessary to determine which forms of knowledge (and therefore, which tools for knowledge generation) can best serve the function of informing deliberation. The following piece of conceptual analysis that contrasts two distinct functions of research shows how we resolved this issue.

Most research activity in science education – as in other disciplines – is designed to explain phenomena and events. Stephen Toulmin speaks of the "explanatory ambitions" of scientists[1] and a glance at any recent program of the National Association for Research in Science Teaching or its journal, the *Journal of Research in Science Teaching,* shows this clearly. This aim, however, is not the only valid one.*

When teachers and policymakers make decisions in their classrooms or jurisdictions, they usually draw upon a very different form of

* We hasten to add that, in the case of research in education, explanatory knowledge is often intended to assist and improve educational practice. That this intention is frequently unrealized has itself been an issue of growing concern in recent years; it has been the object of reflection and explanation in the literature.[2] A systematic account of this matter is beyond the scope of the present work.

knowledge than this formal explanatory type. They use what Freema Elbaz calls "practical knowledge"[3] or what Geoffrey Vickers describes as an "appreciation of the situation."[4] While Elbaz refers particularly to the personal, intuitive knowledge of a situation possessed by an individual teacher, we shall adapt the concept of "practical knowledge" to refer to the totality of information about a situation that one assembles prior to making a decision. And practical research is, then, the process of gathering information for use in such decision making.

These two types of research are crucially different in another way. The results of explanatory research must be generalizable. Other researchers must be able to replicate the research and show that the results do not depend on the time or place but are true generally. By contrast, the results of practical research must be directly relevant to the unique situation at hand. For the teacher or policymaker, the same data may have vastly different significance. Data concerning an atypical school principal may be dismissed as "error" by one but be of key importance and interest to the other.

In the present study, it was clearly practical research that was needed to inform the deliberative process. It is inconsequential that this research cannot be applied to other countries or other times. The knowledge had to be relevant to each province and territory in which deliberative conferences took place during 1983. And since the Science Council of Canada's final report is national in scope, the knowledge had to be relevant to the country as a whole.

Research Program Overview

Four principal projects and a number of additional ones have been undertaken in the context of the study. The relationship of the following major projects to the scope and purpose of the research as a whole is explained below (for a detailed account of the methodology and results of each project, see the appropriate section or volume).

1. Analysis of Science Curriculum Policies (volume I, part two)
2. Analysis of Science Textbooks (volume I, part three)
3. Survey of Science Teachers (volume II)
4. Case Studies of Science Teaching (volume III)

Analysis of Science Curriculum Policies

In every province and territory of Canada, the aims, content and (sometimes) teaching strategies for school science programs are the subject of policies established by the corresponding ministry/department of education. Curriculum guides or guidelines contain statements of these policies and they represent an important though limited part of the database for describing science education in Canadian schools. Such policy statements contain aims for science education at the level of rhetoric (A, see Figure I.2). The major purpose of this research project was to analyze these documents to determine what types of aims are required for science programs.

Science programs do not exist in a policy vacuum. They are set in the context of the complete school curriculum. It was therefore important to gather as much information as possible about the policy context in each jurisdiction to understand each particular science curriculum policy and to compare the policies of different provinces for science teaching. This project thus comprised two subprojects which together provided information about the policy context of science education in Canadian schools. One examines the place of science as a subject in the curriculum and the other, the aims of specific science programs.

Analysis of Science Textbooks

One of the aspects of teaching strategy (T, Figure I.2), often the subject of policy regulation, is the selection of textbooks for use by students. This regulation reflects an assumption on the part of the authorities that one of the principal ways in which the aims of a science program are implemented in practice is through the use of a textbook. Research from many countries tends to support this assumption and data are presented later that indicate the Canadian situation is, generally speaking, no different in this regard.

This being the case, it was important to determine the explicit aims (A) of the textbooks in frequent use, together with their actual curriculum emphases (t). From this information the implicit aims (a) of the books were inferred. A comparison was then made among three versions of aims for science education: A (guidelines), A (textbooks, explicit), and a (textbooks, inferred from t). From such a comparison, an assessment was made of the extent to which the aims stated for teaching science are being realized in practice.

In addition to using the general categories of aims from the policy analysis project, aims based on the criticisms of science education voiced in the discussion paper series were also used as categories for analysis. Interpretive information gathered through interviews, survey data and other research sources supplemented the reports of the policy and textbook analyses. These additional sources are made clear in each instance.

Survey of Science Teachers

For an adequate appreciation of science education in Canada, the study needed to go beyond the documentary analysis of policies of ministries/departments of education and of the textbooks used in schools. It had to gather the opinions of those most intimately involved in the professional practice of science education, namely, the teachers of science. A survey was conducted to determine:

- science teachers' beliefs concerning the importance of various aims of science education;

- science teachers' perceptions of the effectiveness of their teaching in enabling students to achieve the various aims of science education;
- obstacles to the achievement of the various aims of science education.

In short, we asked science teachers about their aims for teaching science (A) (and thus implicitly about the official aims). We also asked about their approaches to teaching (T) and thus about the achievement of their aims. And we asked for information about several of the contexts in which these aims and teaching strategies function, especially about the professional, instructional, institutional and social contexts.

Case Studies of Science Teaching

It is always difficult for research to go beyond the level of rhetoric in describing the state of a practical art because most of the information comes from written or oral accounts by practitioners that are necessarily reflections on their practice. However, case studies in education conducted by trained observers have, in recent years, been increasingly used to penetrate the level of rhetoric and approach more closely the level of practice. In the science education enterprise, studies directed by Bob Stake and Jack Easley for the National Science Foundation in 1977 clearly established the legitimacy and potential value of this type of research.[5] Volume III of this background study presents a series of case studies that provide information about the actual teaching strategies (t) used in classrooms, about the corresponding aims (a) and about the ways in which teachers perceive their instructional, institutional and social contexts.

In their proposal for coordinating this research project, John Olson and Tom Russell are quite clear about the value of such a research strategy.

> "One of the advantages of the case-study method is that the *setting* in which events occur can be portrayed in detail. This detail is essential for helping those who work outside the classroom to appreciate and to assess interpretations of events that occur there. And such appreciation is necessary for informed deliberation about any complex matters of social policy."[6]

Case study research always draws upon any available sources of data to gain a richer and deeper understanding of the phenomena under investigation, and this is also true for the entire research program. During the course of the study, many informal or semiformal interchanges have taken place among Science Council staff and science educators at all levels. From these encounters, much has been learned to help us interpret and understand the data generated by the primary research projects. Wherever possible, our use of such information in these volumes is indicated.

In addition to the four major projects, there are two research projects whose state of progress at the time of writing prevents their inclusion in the present background study. It is intended that two additional studies, one reviewing historical aspects of science education in Canada, and the other documenting statistical trends in enrolment in science courses will ultimately be published. Both of these have obvious though quite distinct contributions to make to deliberations on the future direction of science education.

One of the most intriguing possibilities for a major research program is the preparation of integrated accounts of the results. It might be possible, for example, in the present study, to use the various themes of the study, such as the "Canadian context" theme or the "science education of women" theme, as foci for integrating results from each of the four components of the research program.[7] While the present publication does not attempt such integrated analyses on a thematic basis, the Council's final report on science education does, since policymakers and teachers attend to such themes in their entirety and not in the unintegrated manner in which multiple research projects must perforce treat them.

Part Two

Analysis of Science Curriculum Policies

IV. Science in the School Curriculum

Teaching is a sufficiently complex and important activity that the need to prepare and plan carefully for it is generally acknowledged. Of course, the "curriculum" actually experienced by students in a classroom is not always exactly the one that was planned. Nevertheless, the expectation is that, by making certain strategic decisions in advance, classroom events will have an overall shape and purpose they might otherwise lack. The final curriculum planner is clearly the individual teacher who must plan for each lesson in the light of the specific circumstances at hand. But the substance of a teacher's lesson plan is rarely created *de novo* for each occasion by the teacher working independently from scratch. The decision by teacher X to teach subject-matter topic A using strategy B on a particular day is simply the last in a chain or network of decisions made on previous occasions.

Some of these earlier decisions may have been the teacher's own, made, for example, in the course of planning work for the year or week. But others are likely to have been made elsewhere and intended to cover many similar situations. And whatever the level at which those decisions are made — ministry of education, school district or school — they combine to form a context that limits the scope of the individual teacher's specific planning. All of these limit-setting decisions can be regarded as curriculum policies. However, the policies that have particular impact on the substance of teaching are those issued by ministries of education[1] as curriculum guidelines covering each subject or course at each level of schooling.

More specifically, two types of ministry policies exist both of which affect the teaching and learning of science. One is concerned with general matters — which subjects must be offered in schools, the amount of time to be spent on each subject, the requirements for a student's graduation from high school, and so on. This type of policy sets the policy context within which individual science programs are developed and is the focus of this chapter. The second deals with specific matters — the aims, content and teaching strategies for science programs in schools — and is the focus of analysis and discussion in chapter V.

Policy analyses are important to this study for two main reasons. The major focus of the study is the aims and objectives of science education in Canada, and ministry policies set out the official aims and objectives for science programs in schools. All instructional decisions including the selection of textbooks and classroom activities can, in principle, be assessed by reference to these policies.* Secondly, the analysis of official policies for science education can help to assess the validity of the criticisms of science education. This analysis can help shape deliberation concerning future aims for science education.

Methodology

The subject matter of two other reports is closely related to that of the present one. Both have been prepared for the CMEC and both are used extensively in this study.[2] The first, *Secondary Education in Canada: A Student Transfer Guide*, now in its third (1981) edition, was designed, as its name suggests, to assist secondary schools in placing students newly arrived from another province. It provides a useful overview of general curriculum policies of each province and brief descriptions of secondary school courses in each subject. *Science: A Survey of Provincial Curricula at the Elementary and Secondary Levels*, is one of a series of reports designed to assess the level of uniformity within Canadian curricula. As it examines the science curriculum guidelines of all provinces, it is closely related to the focus of the present study and has been useful as a cross-reference document.

The CMEC reports have their limitations. Neither of the reports includes the territories. Since the Science Council's study includes both provinces and territories, certain additional inquiries were required.** Also, because *Science: A Survey of Provincial Curricula at the Elementary and Secondary Levels* has a purpose and emphasis different from ours, we had to review curriculum guidelines in a different way.

Given this background, project staff followed a four-step procedure to ensure the accuracy of the information in this study. First, ministries in all provinces and territories were requested to send to the Science

* This analysis of the official aims for science education was also used in the analysis of science textbooks (part three of this volume) and in the survey of science teachers (volume II).

** It should be pointed out here that the Northwest Territories follows the general curriculum policies of Alberta; they have also developed, within that policy context, science programs at all levels to meet the particular needs of their students. Similarly, the Yukon Territory follows the curriculum policies of British Columbia but has its own science program at the elementary level.

Council copies of all policy documents relating to science curricula.[3] These were collected during the period February to October 1980. The second step involved summarizing the contents of each and analyzing them using a common set of categories (November 1980 to February 1981).[4] Third, we prepared a draft interim report and circulated it to provincial officials for comment and correction of errors (fall 1981). This process led to a final review and updating of the information for the present study (August 1982).

This study, like all studies of this type, reflects the policies in force at the time at which the documents were collected. Curriculum policies, like other policies, change from time to time and it is both impossible and undesirable to freeze such change for the duration of a study. The CMEC study, though published in 1981, was based on documents collected in June 1979. And our study, published in 1984, is based on documents collected to May 1982. Over one-quarter of the approximately 120 documents that we examined were published during the intervening three years (1979 to 1982).

More specific information about the methodology of each analysis of the documents is provided with the summary results. The remaining sections of this chapter contain information about the range of science courses offered in each province, the requirements for student graduation (with respect to science), the amount of time specified by provincial policy to be spent on science courses, and the processes by which science curriculum policies are developed in each province.

Science Course Offerings

Table IV.1 contains a summary of the science courses available in each province and territory for each of the three levels of schooling.[5] In all provinces, a basic core of science is offered throughout school, beginning with an integrated program in the early years, continuing with a gradual move towards separate science courses during the middle years, and concluding with separate courses in physics, chemistry and biology in the senior years. In addition, each province or territory offers a variety of alternative courses at the senior level. One cannot tell without course enrolment statistics which courses are taken by most students. For example, in the Northwest Territories, it has been pointed out that many more students take a general science course in grade 10 — one specially designed for students in the North — than physics, chemistry and biology courses.

The mere existence of a science course communicates little about the substance of that course. While each ministry requires that science be taught at various levels, local school districts, schools and teachers are expected to interpret and implement such a mandate. Thus, the degree to which science is actually offered depends on many factors. However, ministry policies indicate more than simply which courses are to be offered. Policies also set down graduation requirements for students.

Table IV.1 – Science Course Offerings

Province/Territory	Nfld	PEI	NS	NB	Qué	Ont	Man	Sask	Alta	BC	NWT	YT
Early Years:												
Science[a]	X	X	X	X	X	X	X	X	X	X	X	X
Middle Years:												
Science[b]	X	X	X	X	X	X	X	X	X	X	X	X[d]
Senior Years[c]:												
Biology	X	X	X	X	X	X	X	X	X	X	X[e]	X[d]
Chemistry	X	X	X	X	X	X	X	X	X	X	X[e]	X[d]
Physics	X	X	X	X	X	X	X	X	X	X	X[e]	X[d]
General Science	X	X		X[f]			X[g]		X		X	
Earth Science/Geology	X		X			X				X		X[d]
Physical Science	X[g]	X	X	X			X					
Environmental Science	([h])			X		X						
Ecology/Conservation		X					X					
Oceanography	([h])	X	X									
Agriculture		X						([i])	([i])	([i])		

[a] In the early years, science is frequently taught not as a separate subject but in an integrated manner along with other parts of the curriculum.

[b] In Alberta and Saskatchewan, life science is taught at grade 7, earth science at grade 8 and physical science at grade 9. Elsewhere, each year's program contains topics from several branches of science.

[c] Only courses considered by ministries of education as science courses are listed. Other courses in the school curriculum may, of course, contain a science component, such as Health Education, Technological Studies, and 'People and Their Technology.' See also note i.

[d] The Yukon follows British Columbia curricula for these courses.

[e] The Northwest Territories follows Alberta curricula for these courses.

[f] Course is offered at vocational/practical level only.

[g] Courses are designed for students of lower ability. Not all such courses are listed.

[h] To be implemented in 1983-84.

[i] Agriculture is offered but not as part of a science program. In Saskatchewan, it is part of a Saskatchewan Studies program; British Columbia and Alberta have separate agriculture programs.

Science Requirements for Graduation

In the early years of school in all provinces and territories, students do not choose what to study. Science is mandatory. Table IV.2 shows that this is also the case for most jurisdictions in the middle years. However, at the senior years, where extensive course selection is permitted, different provinces require students to take different numbers of science courses to graduate. In practice, this means that in seven of the 12 jurisdictions, one science course beyond the end of grade 9 is required for graduation. In Manitoba two science courses are required, while Prince Edward Island and Nova Scotia do not require any science courses beyond the grade 9 level for graduation. Québec's new minimum requirements (currently being implemented) include mandatory science courses in grades 7 and 9 followed by one more course at the senior level. In Ontario, beginning in 1984, one science course beyond grade 9 will be required.

Table IV.2 – Science Requirements for Graduation

Province/Territory	Middle Years	Senior Years
Newfoundland	Grades 7, 8, & 9 required	1 course (2 credits)
Prince Edward Island	Grades 7, 8, & 9 required	None required
Nova Scotia	Grades 7, 8, & 9 required	None required
New Brunswick	Grades 7, 8, & 9 required	1 course required
Québec	Grades 7 & 9 required[a]	1 course required[a]
Ontario	Grades 7, 8, & 9 or 10[b]	None required
Manitoba	Grades 7, 8, & 9 required	2 courses required
Saskatchewan	Grades 7, 8, & 9 required	1 course required
Alberta	Grades 7, 8, & 9 required	1 course (3 credits)
British Columbia	Grades 8, 9, & 10 required	None required
Northwest Territories	Grades 7, 8, & 9 required	1 course required
Yukon Territory	Grades 8, 9 & 10 required	None required

[a] In the process of implementation, 1982-86.
[b] Under review, 1982-83.

Listed here are the minimum requirements for graduation, as stated by ministry policy. Individual school districts or schools often have local norms or expectations that raise the minimum requirements. In addition, because most ministries define their complete requirements for graduation in terms of numbers of credits, courses or electives, it may, in practice, be very difficult for a student to meet these requirements without taking a science course beyond those that are formally compulsory.*

* For a more complete understanding of the degree to which science courses are taken beyond the minimum requirements, the reader should consult the course enrolment statistics (forthcoming).

Time Spent on Science

In most jurisdictions, ministries of education specify the amount (or proportion) of instructional time to be spent on each subject or course. Table IV.3 summarizes policies of this type. Again, local factors may affect the actual allotment of time, particularly at the early-years level. To draw conclusions from the data at this stage would be premature and inappropriate. The focus of the study is on the aims of the science programs and the table is included to provide a background or context for the analysis of curriculum guidelines (see chapter V).

Table IV.3 – Time Spent on Science

	Minimum Time Required by Provincial Policy (Hours per Year)[a]		
Province/Territory	Early Years	Middle Years	Senior Years[b]
Newfoundland	35 - 100	100	110 - 120
Prince Edward Island	No stated policy	No stated policy	140 - 150
Nova Scotia	100	100	120
New Brunswick	60	80	140 - 150
Québec	40 - 60[c]	100	135 - 150
Ontario	No stated policy	70 - 110[d]	110 - 120
Manitoba	50 - 100	100 - 110	110 - 120
Saskatchewan	100	105	100 - 120
Alberta	50 - 66	100	75 - 125
British Columbia	47 - 66	100	100 - 120
Northwest Territories	50 - 66	100	75 - 125
Yukon Territory	47 - 66	100	100 - 120

[a] Where necessary, calculated from policy statements on the basis of 180 to 200 instructional days per school year.

[b] Times shown here are hours per course. A student may choose to take several such courses.

[c] First cycle (grades 1-3) = 40 hours; second cycle (grades 4-6) = 60 hours.

[d] Grades 7 and 8 = 70 hours; grades 9 and 10 = 110 hours.

The Development of Science Curriculum Policies

It is natural enough that when people are not content with present policies they not only try to change them directly, they often question the process by which they were generated. Sometimes this questioning may arise from the conviction that a process yielding results of which they disapprove must be flawed in some respect. Alternatively, it may simply be that the process by which policies are developed is not well understood and that the means of influencing the process in preferred directions is therefore unclear. Curriculum policy development, including textbook selection, is a case in point. In recent times, there have been calls for reviews of these processes by individuals and groups with openly declared interests in seeing specific policy decisions made (such as creationist groups and textbook authors whose books have not been approved for use in schools). We have, therefore, felt some obligation in this study to describe the processes used at the provincial level to determine science curriculum policies and to select textbooks.

A word of caution before proceeding. The idea of two levels of reality — a level of rhetoric and a level of practice — is even more applicable to an understanding of policymaking than teaching. How people actually make policy and how they say they make policy are often quite different. And this is not necessarily because the individuals are dishonest but because policymaking processes are notoriously difficult to describe in the sort of detail that enables one to understand how and why particular policies emerge.[6] Case studies would probably provide the clearest insight into these processes but to date no such studies of provincial curriculum policy development have been published. The data collected in this study consist of general information about curriculum guideline revision gathered through informal interviews with ministry officials in each province, together with inferences drawn from the policy documents themselves.

Curriculum Guideline Revision

Curriculum guides at all levels have been undergoing revision during the past few years in most provinces. These new documents often represent radical revisions of former policy documents that had remained substantially unchanged for 10 to 15 years. This latest round of changes is seen in some provinces to be the beginning of a new system of cyclical revision, in which documents are scheduled to be used, reviewed, revised, tested and reissued on a regular three, four or five-year basis. British Columbia, Alberta, Manitoba and Nova Scotia have all reported using this approach. In most other provinces, revisions are irregular responses to perceived needs and the resulting policies remain in force until circumstances demand and resources enable fresh revision.

Rarely do ministry officials act alone in revising guideline documents. Usually an *ad hoc* committee involving teachers is struck to develop a draft document. Saskatchewan and British Columbia, for example, report using school board trustees or officials on these committees, while several provinces involve university scientists and science education faculties. Manitoba has a standing "K-12 science working party," consisting mostly of teachers, that maintains an overview of all science curriculum policy development, appoints *ad hoc* committees and recommends guideline documents to the ministry hierarchy. In Alberta, a "curriculum policies board," reporting to the Minister and including individuals from several different areas of provincial life, supervises policy development in all subject areas. It probably has the most comprehensive mandate of any such provincial committee in the country, facilitating policy coordination among different areas of the curriculum. In other provinces, such coordination is provided by inhouse resources, usually at the assistant deputy minister or branch director level.

The degree to which parents, industrialists, the business community or other outside stakeholders can become directly involved in science curriculum policy deliberation is, in general, very small. There is ample opportunity for teachers and other insiders to make input, since the processes are open. Such processes have the advantage of being fairly simple to manage but the disadvantage of being conservative since few outsiders or even radical insiders become involved.

Policy development involves a complex blending of values with information about the context in which the policies are to function. The use of committees ensures debate over value positions, but their restricted membership means that the range of value positions is rarely very broad. Information about the context — in this case, about the provincial science education system — can be introduced in two ways. Either the participants pool their collective experience or they use systematic data collection. The former can be adequate where the province is small (e.g., Prince Edward Island) or where the participants are carefully selected to reflect the province's diversity (i.e., linguistic groups, economic regions, urban/rural distribution, etc.). The latter process, carefully controlled, can provide more useful information. The clearest example of its use is in British Columbia, where students' learning and teachers' opinions are assessed on a regular basis and the results fed into the curriculum policy process. Some other provinces report the use of some systematic data. However, the majority depend upon the personal resources of their committee members.

In nearly every province, the development of a draft policy document is followed by a limited period of "validation" during which it is sent out to a large number of interested individuals for comment (e.g., Ontario) or for "trial use" (e.g., Manitoba). Following this evaluation process, revisions are made (where necessary) before final approval by the minister.

Textbook Selection

One of the key decisions to be made within the context of determining a new science curriculum policy is concerned with the selection of textbooks for student use. Textbooks (see part three) are a key component of any curriculum and the process of their selection is of obvious educational significance. But as textbooks are professional as well as commercially profitable products, their selection is a matter of professional and commercial interest to authors and publishers.

Every province uses some form of listing of textbooks for student use. In some cases, lists prescribe mandatory texts. In others, the listing indicates that schools are able to obtain a price break on a particular book if it is purchased through the ministry. Some provinces list only one or two books for a particular course or level; others (e.g., Québec and Ontario) list many books from which schools or teachers may choose (see chapter V and part three for more detail).

Although most provincial officials will state that textbooks should be used as "resources to support a particular course and not as the course of study itself," the curriculum guidelines themselves vary considerably in their application of this principle. At one end of the scale, the guideline identifies no textbook; the content topic headings and aims of science education have been developed with no particular textbook in mind. Subsequently (and in the cases of Ontario and Québec in a separate policy document) textbook resources are listed for the course. Here, the process is one of defining aims and topics first and selecting textbooks second. At the other end of the scale, curriculum guidelines identify one or more textbooks at the outset and the topics and aims in the guidelines correspond directly to those textbooks. Here one must assume that textbook selection was the controlling decision and that enumeration of aims and topics has followed. These examples are, of course, the extremes. In many instances, textbook selection and decisions about the aims of science education are made together.

We wish to stress that we are not in any way advocating one process rather than another. Often, extra-educational factors dictate the choice of process. For example, when a new guideline is issued in Ontario, commercial publishers contract authors to write textbooks to correspond to the new guideline. These are then submitted for provincial approval and listing. The province is large enough for the operation of a relatively free market, which is further stimulated by a ministry policy of not listing books authored or published outside Canada unless suitable Canadian books are unavailable. In many smaller provinces, however, because the potential market is too small for normal commercial production and competition, the significance of the ministry's curriculum decisions is severely restricted. In some situations (e.g., in Newfoundland, early years), only one book is listed and a commercial publisher is given a monopoly in exchange for preparing a special edition for the province. In Québec, through the intervention of its "Direction du matériel didactique," the Québec ministry commissions textbooks from publishers to fit its new curriculum guidelines. Elsewhere, textbooks are selected from various sources by a committee or by ministry officials.*

* Several recent studies of educational textbook publishing in Canada give further information on this complex topic.[7]

V. The Official Aims and Strategies of Science Education

While the policy context in which science curricula are developed is of obvious importance to practitioners, the chief focus of the present study is the substance of these science curriculum policies. What are the aims and objectives for which science is being taught and how are teachers expected to achieve these aims? At least, what are the *official* aims and strategies that ministries of education intend to be implemented?

Science curriculum guidelines from each province contain ministry policy in regard to three key components of the science curriculum.

- Content of science teaching: *What to teach in science?* or Which science topics are teachers expected to cover in their courses?
- Aims of science teaching: *Why teach science?* or What are mandated as the purposes or objectives of science courses?
- Strategies of science teaching: *How to teach science?* or Which methods, textbooks, or instructional techniques are approved (or prescribed) for teaching science courses?

Curriculum guidelines may also contain other information, such as time to be spent on individual parts of a course or guidelines for student evaluation. Sometimes these additional topics have the force of policy, sometimes they are simply advisory. In any case, all science guidelines contain the three components noted above and our first task in analyzing provincial science guidelines was to separate these logically distinct parts. (Appendix A lists the guidelines analyzed in this study.)

Content of Science Teaching

We decided not to examine the area of "content" any further for two principal reasons. First and most important, the issue of which science topics are taught at each level of school is not central to the objectives of the study. The study's objectives are concerned with aims and purposes and with strategies for reaching these aims rather than with the science topics which form the substance of school programs.

The second reason for setting the "content" category aside was that the CMEC study, *Science: A Survey of Provincial Curricula at the Elementary and Secondary Levels*,[1] contains detailed content summaries for each of the three levels. On the basis of their examination of this component of the curriculum guidelines, that study's authors, Haggerty and Hobbs, conclude that, while "substantial similarity" in course content exists in the early years, there is "even greater commonality" at the middle years, "the trend continuing to greater commonality" in the senior years.[2] They also point out that the existence of "local options" in many cases means that one cannot infer from the general conclusion (of commonality of topics in guidelines) that common topics are actually being taught in schools across Canada. The present study can endorse this qualification on the basis of our general experience (and on the basis of the case studies in volume III).

Aims of Science Teaching

As we examined the many statements of aims for science education in the guidelines of the various ministries of education, two features became immediately obvious. First, as a group they are diverse. They represent as broad a range of objectives as one is likely to encounter in the practice or literature of science education, at least in North America. Second, many statements, while superficially different in form, appear to represent similar ideas. The diversity of statements called for a system of classification that would permit sorting prior to identifying general conclusions.

Eight categories were used for this classification — a large enough number for reasonably precise definition, but not so large as to make the task impossibly difficult. While the eight categories were derived inductively from an examination of the guidelines themselves, there is a strong correspondence between them and the sets of categories used by other researchers in the field.[3] Table V.1 lists the eight categories, together with an example illustrating an objective from each category. Because these categories of aims occupy a central place in several components of the research program, some further comments on each appear below.

Science Content

Some of the aims for science education most frequently encountered at the level of practice, if not at the level of rhetoric, are that students should know, understand and, in various ways, be able to manipulate the substance of scientific knowledge.[4] Such aims stress the value of a command of the products of scientific endeavour rather than the processes of its development and application. This is frequently held to be important by teachers at higher levels of schools and by colleges for teachers at lower levels. The importance of scientific knowledge both for its own sake and for (later) study or use is stressed here.[5]

Table V.1 – Categories of Aims for Science Education

Category	Illustrative Example
1. Science Content	"To increase the student's knowledge of basic concepts in life, earth, and physical sciences" (Manitoba)
2. Scientific Skills/Processes	"To develop facility in using the methods and tools of science" (New Brunswick)
3. Science and Society	"To promote an understanding of the role that science has in the development of societies and the impact of society upon science" (Alberta)
4. Nature of Science	"To develop student appreciation of science as a way of learning and communicating about the self, the environment and the universe" (Saskatchewan)
5. Personal Growth	"To develop as an autonomous and creative individual who will live in a scientific and technological society" (Québec)
6. Science-Related Attitudes	"Create an enthusiasm for the method of thinking that uses observed facts as data in a logical method of solving problems" (British Columbia)
7. Applied Science/Technology	"Students should be exposed to a representative sample of the technological applications of science — communications, transportation, scientific research, medicine, architecture, computers, household appliances, energy" (Newfoundland)
8. Career Opportunities	"To relate science to career opportunities in technology, industry, commerce, business, medicine, engineering, education, research and other areas in which science plays a role" (Ontario)

Scientific Skills/Processes

In recent years, aims concerned with developing so-called "process skills" have become very popular among science educators. This involves developing the skills of the scientist (best exemplified, perhaps, by the elementary science program, *Science – A Process Approach*[6]) such as observing, classifying, measuring, inferring, hypothesizing and so on. The CMEC report on science curricula cites a list of process skills from the Manitoba middle-years guideline, but nearly all provinces issue similar lists, and many curriculum projects and textbooks in recent years have claimed to provide for the development of process skills. Munby's discussion paper[7] urges science educators to reflect critically on the important objective of scientific thinking.

Science and Society
Aims concerning science content have presumably always been present in curriculum guidelines and those focussed on skills and processes have been popular for over a decade. However, objectives in the "science and society" category are newer as popular faith in the social and economic potential of science has waned. Aims in this category focus on the interaction between science and society and particularly on such ethically problematic areas as energy, genetic engineering and the problems of industrial waste. As yet, few curriculum materials have aims in this area as their primary focus[8] but the importance of such aims for an informed citizenry has been increasingly stressed.[9] James Page's concern for a "Canadian context" for science education falls within this category.

Nature of Science
These aims stress the processes of scientific inquiry rather than its products. However, unlike the category of skills and processes, these aims intend the student to understand how science, as a discipline, "works." Topics from the history of science are often used here to help the student understand some point about, for example, the development of theories, the use of evidence or the nature of scientific discovery. The series of secondary school science curricula developed in the 1950s and 1960s as a result of funding by the (US) National Science Foundation – *PSSC Physics, CHEMStudy* and *BSCS Biology* – are classic examples of this type of curriculum.

Personal Growth
For some people, all teaching and learning of school subjects, including science, is justified in terms of individual, intellectual, moral and social growth – goals of education common to all subjects. This presents the problem for science educators: "How can learning science contribute to the attainment of these goals?" Several ministry guidelines show a variety of attempts to deal with this problem. Aims in this category stress the development of such qualities as creativity, autonomy, cooperation, teamwork, a sense of responsibility and even patriotism. As "science content" aims are silent about the ultimate purposes of learning

science, so "personal growth" aims are equally silent about how science teaching is expected to contribute to a student's personal growth.

Science-Related Attitudes
Aims involving the development of various "attitudes" abound in ministry guidelines, textbooks and curriculum projects. There are least two major groups of these attitudes. The first comprises attitudes held to be characteristic of scientists — "intellectual honesty, humility, open-mindedness, willingness to investigate, desire for accurate knowledge"[10] and the like. The second consists of attitudes which students are intended to develop towards science, scientists or scientific activity, such as interest, enthusiasm, appreciation or excitement. For the purposes of the present analysis, we have grouped both of these together while recognizing that, pedagogically, it is probably not useful to do so.[11]

Applied Science/Technology
These aims focus upon informing the student of the uses of science in industry, medicine or other technological fields. Having been very popular in secondary school science education in the 1940s and 1950s, such aims were largely displaced by those relating to the nature of science. Recently, however, there seems to be a renewed interest in these practical aims. The category is broad, ranging from such aims as those advocated by Donald George in his discussion paper, *An Engineer's View of Science Education,*[12] to those contained in the series of chemistry textbooks called *ALCHEM,* which describes the applications of chemistry in industrial processes.[13] Another aspect of the "Canadian context" theme is involved here of course. Aims which stress the application of science in technology can do so using Canadian examples and thus fulfill both aims simultaneously.

Career Opportunities
The potential for science education to contribute to the eventual employability of students is often interesting to the students themselves. It is of even more general concern at times of economic recession or when technological advances seem to be overtaking the former employment prospects of many people, especially women. Aims in this area tend to be contentious and hotly debated by academics who do not see job training as a proper function for their institutions. However, ministries of education do state such objectives and, while nobody seriously contends that high schools are primarily job-training institutions, it would appear equally simplistic to argue that they have no responsibilities in preparing students for future careers. The potential for science

education to contribute to this function of school thus gives rise to this category of objective.

Analyzing the Ministry Guidelines

These eight categories of aims for science education are the tool with which we analyzed the statements contained in ministry guidelines. This analysis is not an exact scientific classification. Analyzing with categories such as these is an instance of what Max Black calls "reasoning with loose concepts."[14] The categories themselves are not precise or well defined; they cannot be. It is a matter of judgement when one assigns a "border-line" objective to a particular category, and we have used our best judgement and have been aided by the critical commentary of ministry officials. The analysis is simply intended to be useful. The three levels of schooling — early, middle and senior — are the basis for separate analyses (see Tables V.2 to V.6). Note that New Brunswick has two columns in each of the tables, corresponding to the independently developed English and French programs.

Early Years

Table V.2 shows the results of analyzing the aims of science education set out in the early-years guidelines according to the eight categories of aims. There appears to be a consensus regarding aims at this level among all provinces and territories. Four categories of aims appear in all guidelines at this level: science content, scientific skills and processes, personal growth and science-related attitudes. Three categories — nature of science, applied science/technology and career opportunities — do not appear in any guideline. Some difference of opinion exists over the science and society aim; five jurisdictions include aims of this type. However, aims referring to such matters as the development of a concern for the environment were classified as science and society, and several provinces include environmental studies as part of the content of the early-years course. This analysis therefore confirms the trend, identified by Haggerty and Hobbs, that the general goals of science education at the early years stress "process skills and attitude development."[15]

Middle Years

The science curriculum guidelines for the middle years are more recent than those for the early years. With one exception, all guidelines have been revised within the past five years. Table V.3 shows the results of the analysis of the aims for this level. There is a distinct shift in priorities from those of the early years. Science content is learned for its own sake although process skills are also stressed and science and society aims appear in every guideline. Science-related attitudes, while they appear in

Table V.2 – Aims of Science Education – Early Years

Province/Territory	Nfld	PEI	NS	NB(E)	NB(F)	Qué	Ont	Man	Sask	Alta	BC	NWT	YT
Year of Guideline	1978	([a])	1978	1982	1977	1980	1975	1979	1971	1980	1981	1978	1978
Science Content	X	X	X	X	X	X	X	X	X	X	X	X	X
Scientific Skills/Processes	X	X	X	X	X	X	X	X	X	X	X	X	X
Science and Society	X					X	X			X		X	
Nature of Science													
Personal Growth	X	X	X	X	X	X	X	X	X	X	X	X	X
Science-Related Attitudes	X	X	X	X	X	X	X	X	X	X	X	X	X
Applied Science/Technology													
Career Opportunities													

[a] Document undated.

Table V.3 – Aims of Science Education – Middle Years

Province/Territory	Nfld	PEI[b]	NS	NB(E)	NB(F)	Qué	Ont	Man	Sask	Alta	BC[c]	NWT	YT[d]
Year of Guideline	1980	([a])	1977	1980	1979	1980	1978	1979	1979	1978	1982	1979	
Science Content	X	X	X	X	X	X	X	X	X	X	X	X	
Scientific Skills/Processes	X	X	X	X	X	X	X	X	X	X	X	X	
Science and Society	X	X	X	X	X	X	X	X	X	X	X	X	
Nature of Science	X			X			X		X	X	X		
Personal Growth			X			X					X		
Science-Related Attitudes	X		X	X	X	X	X	X	X	X	X		
Applied Science/Technology	X	X				X	X				X	X	
Career Opportunities							X			X			

[a] Document undated.
[b] Aims are not stated explicitly.
[c] Draft document only.
[d] Yukon follows BC program.

nine guidelines, are not stressed to the same degree as at the early years. Finally, a number of guidelines stress the applications of science. It is clear that programs at this level are intended to achieve a wider variety of aims than those at the early level, and that a fair degree of consensus exists among the various ministries concerning what those aims should be.

Senior Years

Since biology, chemistry, and physics are offered at the senior-years level in every province, we decided to analyze only the guidelines corresponding to these courses. The reader should consult enrolment figures for an appreciation of the degree to which these courses are representative of the science taken by most students at this level, but these are probably the chief options for most Canadian students. Tables V.4, V.5 and V.6 show the results of analyzing guidelines in biology, chemistry and physics. Two immediate patterns are evident. There is less agreement about aims at the secondary level and there is a broader range of aims than for either of the other two levels. An increased concern for learning about the nature and applications of science is notable. Correspondingly, there is less emphasis on aims concerning "personal growth" and the development of attitudes. The inclusion of "science and society" aims seems to be related to the date of the guidelines: these aims appear more frequently in the most recently published documents.

A number of questions arise from the results of this analysis but since several involve both the aims themselves and the strategies recommended for their attainment, they are discussed after the review of ministry policies concerning textbooks and teaching strategies.

Strategies of Science Teaching

To achieve a variety of education aims, a corresponding variety of teaching strategies is required.[16] Therefore, the study examined curriculum guidelines that prescribed strategies for the achievement of the stated aims. In general, guidelines provide few strategies for teachers; those that appear are reviewed briefly below.

The chief policy instrument used by all ministries to control or influence teaching strategies is the prescription, authorization or approval of textbooks for student use. The degree of regulation varies from province to province. Some provinces (such as British Columbia) make mandatory a very limited range of textbooks at each level. Other provinces (such as Ontario and Québec) authorize a very wide selection from which schools or teachers may choose. Elsewhere, guidelines list from two to six approved books and schools or teachers may use any of these they choose. In some jurisdictions, other (unlisted) books may be used, although the cost of such books may be higher (if listed books are sold through the ministry at special rates).

Table V.4 – Aims of Science Education – Senior Years (Biology)

Province/Territory	Nfld	PEI[a]	NS	NB(E)	NB(F)	Qué	Ont[a]	Man[b,e]	Sask[c,e]	Alta[e]	BC[c]	NWT[d]	YT[d,f]
Year of Guideline	1982		1978	1980	1972	1971		1981	1971	1977	1974		
Science Content	X		X	X	X	X		X	X	X	X		
Scientific Skills/Processes	X		X	X	X	X		X	X	X			
Science and Society	X		X			X		X		X			
Nature of Science	X			X	X	X		X		X			
Personal Growth			X										
Science-Related Attitudes			X	X	X								
Applied Science/Technology	X		X	X									
Career Opportunities													

[a] Guidelines being revised; no analysis possible.
[b] Pilot program.
[c] No aims stated in guideline.
[d] NWT follows Alberta program; Yukon follows BC program.
[e] Science as a foundation for further study is emphasized.
[f] Additional aims (in categories 5, 6, and 7) are specified in an overview of aims of secondary school science.

Table V.5 – Aims of Science Education – Senior Years (Chemistry)

Province/Territory	Nfld	PEI[a]	NS[e]	NB(E)	NB(F)	Qué	Ont[a]	Man[b]	Sask[c]	Alta[f]	BC[c]	NWT[d]	YT[d]
Year of Guideline	1982		1977	1979	1980	1976		1981	1976	1977	1978		
Science Content	X		X	X	X	X		X	X	X	X		
Scientific Skills/Processes			X		X	X		X		X			
Science and Society	X				X	X		X	X	X			
Nature of Science	X		X		X	X		X	X	X			
Personal Growth													
Science-Related Attitudes			X		X	X							
Applied Science/Technology	X		X		X	X		X	X	X			
Career Opportunities								X		X			

[a] Guidelines being revised; no analysis possible.
[b] Pilot program.
[c] Aims not stated explicitly in guideline.
[d] NWT follows Alberta program; Yukon follows BC program.
[e] Science as a foundation for further study is emphasized.
[f] Additional aims (in categories 5 and 6) are specified in an overview of aims of secondary school science.

Table V.6 – Aims of Science Education – Senior Years (Physics)

Province/Territory	Nfld	PEI[a]	NS[d]	NB(E)	NB(F)	Qué	Ont[a]	Man[b]	Sask	Alta[e]	BC	NWT[c]	YT[c]
Year of Guideline	1982		1977	1979	1974	1980		1981	1976	1977	1981		
Science Content	X		X	X	X	X		X	X	X	X		
Scientific Skills/Processes	X		X	X	X	X		X	X	X	X		
Science and Society	X			X		X		X	X	X	X		
Nature of Science	X			X		X		X	X	X	X		
Personal Growth													
Science-Related Attitudes	X		X		X			X	X	X	X		
Applied Science/Technology	X		X		X			X	X		X		
Career Opportunities								X		X			

[a] Guideline being revised; no analysis possible.
[b] Pilot program.
[c] NWT follows Alberta program; Yukon follows BC program.
[d] Science as a foundation for further study is emphasized.
[e] Additional aims (in categories 5 and 7) are specified in an overview of aims of secondary school science.

Appendix B contains a list of 174 textbooks listed by ministries of education (in the most recent documents available). This list only includes textbooks for student use which cover a complete course or a large part of one (i.e., not kits of equipment, audiovisual packages or single-topic books). This list does not necessarily reflect all books in use in Canadian schools. In some schools, books formerly listed but now officially dropped are still used. Schools in some provinces have the right to use books not approved by the ministry. General comments about the selection of textbooks approved for use at each level follow. (For a detailed discussion of individual textbooks, their usage and content, see part three.)

Early Years

Ministry guidelines prescribe almost no teaching strategies at this level except for general injunctions that the program should be "activity-based" or that teachers should use the "inquiry approach." In Alberta, the latter term is defined in terms of students developing and practising "process skills." Elsewhere this term is often used but not elaborated on. In most guidelines, the content is divided into small units and, occasionally, student activities are suggested for teaching this content. However, strategies for teaching are never cross-referenced to specific aims and it is generally assumed that decisions in this area are best left to the teacher.

A total of 36 textbooks are listed for use at the early–years level across Canada, 20 of which appear on more than one provincial list (see Appendix B for more details). Their use may be significantly different from the pattern of ministry listings. Information about this was collected through a survey of teachers and is reported in part three. Part three also discusses the aims and characteristics of those books identified as being used most frequently.

Middle Years

As in the early years, the curriculum guidelines prescribe few teaching strategies, leaving these decisions to the teacher. Again, several guidelines stress an "activity approach." Some 53 textbooks are listed across the country, 21 of these appear in more than one list, and only 9 in more than two. It was therefore difficult to compile a comprehensive and representative list (see Appendix B for the complete list and individual provincial documents for more specific provincial lists).

Senior Years

Mere topic listing and textbook prescriptions are the norm here. In biology, 23 books are listed, 13 appearing more than once; in chemistry, 29 are listed, 16 more than once; and in physics, 32 are listed, and 10 appear more than once (see Appendix B for detailed listings of these books).

Conclusions: Questions for Research and Deliberation

During the course of analyzing the ministry policy documents, a series of questions emerged about the study's overall goal of stimulating deliberation about the future directions of science education. Most of these questions cannot be answered definitively at this stage. More research may be required. Also many of the questions involve value issues that require a position to be taken rather than an answer calculated — they must be responded to through deliberation in each jurisdiction.

The questions are classified into groups. The first two questions concern the overall orientation of science in schools; numbers 3 to 6 focus on specific aims for science education; and number 7 discusses the themes brought out in the Science Council's study in relation to provincial science curriculum policies.

Orientation of Science in Schools

1. The number, variety and balance of aims for science education : How many different objectives can a science program be expected to reach? As we examined a number of the provincial documents, this question arose in our minds frequently. Some documents specify as many as 10 different aims for a single science program. Guidelines at the middle and senior years often stipulate a broad range of aims (see Tables V.3 to V.6, pp. 67-71). Can a program enable students to achieve many objectives or can only a few be achieved thoroughly? No guideline document sets out any order of priority of aims. Can one assume therefore that all of the stated aims are equally important? If not, what is the proper balance for many varied aims? These issues call for clearer resolution than is provided in most ministry policies.

The problem becomes of particular practical significance when one considers whether instructional resources are adequate to meet many varied objectives in science education.* In other words, is the range of textbooks listed by ministries adequate to meet the range of stipulated objectives — as distinct from the range of content topics — specified in the guidelines? What additional provisions are schools and teachers expected to make to ensure that opportunities exist for the attainment of the broad arrays of aims?

One way of approaching answers to these difficult questions is to ask: "What practical difference to the day-by-day teaching of science would it make if each one of a ministry's aims were separately dropped?" If the honest answer, in any given instance, is that no difference would result, one may indeed question the function of that

* For an examination of the objectives of the specific textbooks most often used see part three.

particular aim. The insertion of an aim in a guideline for rhetorical purposes – because, like motherhood, one cannot be against it – is not only useless window dressing, it serves to blunt and confuse what could be an incisive direction to science teachers. Moreover, in some guidelines, an impressive set of general aims for a program is followed by sets of course objectives that, even taken together, do not amount to the overall aims. As we have noted earlier, the aim or purpose of a science program can be of great significance for the students. If there are too many different aims, if they are vague or carelessly stated or if those specified are not perceived by teachers to be attainable, then they will likely be ignored. Ministries of education will then have little control over the direction of resulting programs.

2. *The relation of science to other subjects* : A number of guidelines for the early years refer to the need to relate science to social studies. The inclusion of environmental studies at this level provides an excellent opportunity for this integration to take place. At the middle years in Atlantic Canada and Ontario, science is integrated with other subjects, whereas in western Canada, life science, earth science and physical science are presented in separate years. Apart from these two instances, the relation of science to other subjects in the curriculum is almost never discussed. How then is the teaching of science supposed to relate to the teaching of social studies (at higher levels of school, especially), to the teaching of mathematics and to the teaching of so-called technological (or technical) subjects? These questions need resolution in practice and at present there appears to be little ministry-level direction.

Specific Aims for Science Education

3. *The learning of science content as an objective* : Not surprisingly, perhaps, the aim most frequently encountered in guidelines at all levels was for students to learn something of the content of science. Clearly, in a science course, science content must be present. But often, especially at the early years, one hears the claim that the chief function of content is to act as a vehicle for reaching other educational goals. Yet, as even a brief examination of many guidelines can demonstrate, the detailed arrangement of the science topics to be learned frequently occupies most of the document. Science educators must ask themselves carefully and critically what is the real balance of importance between the learning of content and other objectives. This is of practical significance on a day-to-day basis when teachers and, increasingly, ministries also attempt to evaluate students' achievement.

4. *Process skills* : If learning science content is the aim most often encountered, then the development of "process skills" is a close second. As indicated earlier, several lists of these skills exist in various guidelines but

rarely, if ever, is any advice provided stating which skills are feasible for a given level. Consequently, a list which includes as diverse a collection of skills as "observing," "controlling variables" and "theorizing" is appended to guidelines for programs at all levels for students at various stages of intellectual development. Clearly, some skills cannot be developed at the elementary level while others are likely redundant at the senior level. Yet, rarely is a hierarchy of skills cross-referenced to different grades, ages or developmental levels. Such a casual approach to objective setting can result in only the lowest-level skills being attended to or the total neglect of higher-level inquiry skills. It would appear that the justification for including this objective at the senior-years level — that the development of such skills can enhance the student's ability to "solve problems" in life generally — should be particularly questioned. Marcel Risi's discussion paper[17] moves one to doubt the validity of such a claim.

5. Science-related attitudes as objectives : This category incorporates two different types of attitude: attitudes held to be characteristic of scientists and attitudes towards science, scientists and scientific activity. Aims designed to develop both types of attitudes are encountered at all levels without any indication as to how a teacher should engender such attitudes. It has even been suggested[18] that developing an attitude towards something entails taking a value position towards it, and that deliberately causing students to take up a position of, say, valuing science must involve indoctrination on the part of the teacher. The argument concludes that if the process cannot be a rational one, then it is unethical to conduct it as part of public education. While the reader may not find such an argument entirely convincing, he or she may nevertheless ask how such aims can in fact be achieved in a defensible manner.

6. Science and society and applied science/technology objectives : Several critics of science education complained that not enough attention was paid to the interaction of science and society. As well, popular wisdom in schools often regards ministry policies as following rather than leading curriculum change. But aims dealing with understanding aspects of the interactions among science, technology and society are clearly appearing more often in ministry guidelines. How can we explain this paradox? Are textbooks lacking in this area, do teachers not rate these aims as important or are the critics and popular wisdom wrong?

The Study's Themes in Relation to Provincial Science Curriculum Policies

7. Issues from the study's discussion papers and workshops : During this analysis, we were concerned to see whether the issues raised by the discussion paper series and their implicit criticisms of science education (see

Table II.1) appeared in the guidelines. The issue of a Canadian context for science education appeared only occasionally. For example, the Northwest Territories provides programs designed to help students understand science as it applies to their unique northern environment; Prince Edward Island has an agriculture component in its middle-years science program. No guidelines referred to the processes of engineering though some mentioned technology and the products of applied science. And no guideline at any level made any statements concerning the needs of both girls and boys. Apparently, ministry policy statements do not generally consider these important. Whether or not they are important is clearly a matter for deliberation within each province.

Further issues for deliberation are set out in the textbook analysis (part three), the survey of teachers (volume II) and case studies (volume III). But while research may clarify the issues, the task of deciding and choosing must rest with those in each jurisdiction who are charged with responsibility for developing policy. It is their task that the process of deliberation is intended to facilitate.

Part Three

Analysis of Science Textbooks

VI. Textbooks in Science Education

The aims of science teaching, as set out in official policies, are either in harmony or conflict with two other sets of intentions, namely those of teachers (see volume II) and those found in textbooks. Part three of the study focusses on textbook aims and summarizes the degree of overlap with those of teachers and policy documents. Of course, an account of the intentions expressed by authors of science textbooks, however complete, is an inadequate basis for us to evaluate the ways in which textbooks affect educational practice. Textbooks, as we shall demonstrate, are still one of the principal ways of reaching the aims of science curricula; the present analysis therefore examines the opportunities textbooks provide for students to achieve these aims. Finally, this section will enable the reader to determine the extent to which certain criticisms of science education in general are specifically applicable to science textbooks.

In order to make clear the importance of textbooks both as a tool in science teaching and also as an economic commodity, discussion of the methodology and results of the analysis is prefaced by a few comments on the place given to textbooks in official guidelines, their role in science classes and their place in the educational publishing market.

Official Policies

Despite the upheavals science education has gone through in the last 20 years, the textbook has continued to play an important part in the enterprise. Its function, however, has changed. Not long ago, the textbook was not only the sole reference work available to students — it was, for all practical purposes, the entire program. Since the beginning of the 1960s, the shift of emphasis towards training in the scientific method and a concern for individualized instruction have led educational authorities to recommend the use of several textbooks rather than a single one. The following excerpt from an official document of the Ontario ministry of education illustrates this trend:

> "There is need to recognize the trend away from the use of a single text per grade as the principal instrument of instruction, and towards the use of a variety of books in any subject area. Educational research has confirmed the fact that the rate and degree of pupil growth and maturity vary. Teachers must be provided with an ever-increasing selection of books and instructional materials in order to be able to choose those that meet the different needs and aptitudes of their pupils.
>
> "Similarly, children must have access to an ample variety of print materials if they are to develop facility in choosing those appropriate to their immediate needs."[1]

The Québec ministry of education has recently begun a radical revision of the role of the textbook. In the policy statement and plan of action, "The Schools of Québec," the following illustrates clearly how certain provinces are moving towards a textbook-centred program:

> "The present situation obliges the Ministère to take steps to restore the textbook to its primary role among teaching materials and to emphasize its value as a basic teaching tool."[2]

The Saskatchewan department of education, in its directives concerning textbooks, after discussing the advantages and disadvantages of a single textbook, suggests a compromise:

> "Although the single textbook option is not the most highly recommended approach, it may be a reasonable starting point. Working with their own copies of the other textbooks, teachers will find which ones are most useful and can accumulate, year by year, additional copies for student use. In this way, a gradual transition to the multi-textbook approach can be achieved."[3]

Thus, whatever their position regarding the number of textbooks to be used, ministries of education agree that textbooks play an important role as a teaching tool.

Whether or not a particular textbook is used in a given science classroom depends on a number of factors, the most important being the approval, authorization or prescription of ministry policy. This factor, although essential, is not by itself sufficient. Intermediary bodies (school board and/or school) also have a say in the matter, and this includes financial considerations. And in the end, the teacher usually has the final choice. For the purposes of our study, we examined the considerable variety of science textbooks in use in Canadian schools. Appendix B lists 174 titles prescribed, approved or authorized by ministries. Even allowing for a reduction in this number to account for the existence of both French and English versions of the same text, the list remains impressive. Furthermore, our survey shows that the more than 4000 respondents use roughly 250 different titles, some of which do not even appear in official policies.

The Importance of Textbooks to Teachers

The survey of science teachers asked three questions about textbooks: their use in classes, their usefulness in course preparation and who, according to teachers, should be responsible for their selection. Both the questions and the detailed results are found in volume II. Here we merely indicate the broad trends that emerge from the responses.

Textbook use by students varies greatly from province to province. For example, in Canada as a whole, about six out of 10 teachers in the early years indicate that their students do not use a science textbook. In itself this information is hardly significant unless we add that this proportion varies from about 3 per cent in Newfoundland to about 90 per cent in Ontario. In the middle and senior years the differences between provinces decrease: the proportion of science teachers whose students use a science textbook rises from about 75 per cent in the middle years to 90 per cent in the senior years.

While many students do not use science textbooks during instruction, their instructors and teachers do use them to prepare their lessons. The survey asked respondents to appraise the relative usefulness of 13 teaching aids in the preparation of science lessons. The replies of teachers in the early years differ from those of their colleagues at higher levels. Curriculum resources from the school library were rated as fairly or very useful by 80 per cent of early-years teachers while 65 per cent of these teachers feel the same way about curriculum materials prepared in their school or school board. Finally, 62 per cent agree that the textbooks approved at the provincial level are fairly or very useful in lesson preparation.

At the middle-years level, 77 per cent of science teachers find textbooks other than the approved ones to be fairly or very useful; 73 per cent feel this way about approved textbooks and 70 per cent share this view about materials from the library.

At the senior-years level, 83 per cent and 78 per cent of science teachers consider textbooks other than the approved ones fairly or very useful in preparing their lessons; 78 per cent rated approved textbooks in this way; and 70 per cent of them feel this way about materials such as science magazines, journals and newsletters.

For a detailed presentation of the responses to these questions, see volume II. Here we focus on curriculum resources that most teachers find useful in lesson preparation. It is interesting to note that teachers view textbooks (both those approved and others) as useful aids in the preparation of science courses, that agreement on this point increases with grade level, that curriculum resources from the school library are considered less and less important from primary to the end of secondary school, and that textbooks other than the approved ones are perceived to be useful in course preparation, more useful in fact than the approved ones.

The survey also asked science teachers to indicate which of six listed authorities should be responsible for selecting textbooks. At all three levels, the teachers, in a proportion varying from 44 per cent to 52 per cent, support the proposal that a committee of teachers at the school-board level should be given the responsibility for selecting textbooks. All other authorities receive less than 14 per cent support. Fully half the teachers, therefore, want to be responsible for choosing textbooks and want this responsibility to be exercised at the school-board level (see volume II for more information).

None of this can show us how textbooks are actually used in practice. If textbooks really are used, how are they used? The reader will find answers to some of these questions in the series of case studies undertaken during the fall of 1981 in eight Canadian schools (see volume III).

Science Textbooks and Teacher Satisfaction

In section 3 of the questionnaire, the teachers were asked whether a science textbook was used by the students in the class that they taught most often in 1981 to 1982. Out of 4206 respondents, 2631 answered in the affirmative; of these, 1927 teachers evaluated the following 10 aspects of the textbooks they were using:

1. appropriateness of the science content for the grade level taught;
2. relationship of the text's objectives with the teacher's priorities;
3. readability for students;
4. illustrations, photographs, etc.;
5. suggested activities;
6. Canadian examples;
7. accounts of the applications of science;
8. appropriateness for slow students;
9. appropriateness for bright students;
10. references for further readings.

Respondents were also asked to give their overall impressions of the textbook used (see volume II).

In this section, we examine in greater detail the results of an analysis of 50 textbooks (or series of textbooks) that, according to the survey data, are the ones most frequently used in Canadian schools (see Appendix C for tabular results). The tables show a number of significant trends. First, teachers are generally quite satisfied with their textbooks. Of the 50 textbooks, 36 are considered completely or fairly adequate by two-thirds or more of their users. This is the case for all the physics textbooks and almost all the biology and chemistry textbooks used at the senior-years level. Moreover, only three textbooks are considered completely inadequate, two of which were evaluated by only five or six respondents. The rest of the textbooks (11 out of 50) were rated as mediocre or fair. All but two of the French-language textbooks fall into this category, but in view of the small number of respondents who evaluated these textbooks, it would be premature to attempt to draw any definitive conclusion.

With one exception, the most frequently used textbooks are also those which create the best overall impression. At first sight, therefore, it does not appear that teachers are often forced to use textbooks with which they are not satisfied.

In Appendix C, the features of textbooks that were evaluated are ranked by degree of adequacy, making it possible to determine quite quickly which features are considered adequate or inadequate by the largest number of respondents. For example, the presence of illustrations is the most appreciated feature of almost all the early- and middle-years biology textbooks, while, at the other extreme (for these same textbooks), appropriateness for the slow student is the least adequate feature (this was ranked last 10 times out of 13). Indeed, this feature is inadequate in almost all textbooks; it is ranked tenth (least adequate feature of all) for 24 of the textbooks and ninth for 18 others. So teachers are saying that their textbooks are of little use in helping students with learning difficulties.

Since our study is particularly concerned with the aims of science teaching, one particularly interesting feature is the correspondence between a textbook's objectives and the educational priorities of the teachers using it. For 28 of the 50 textbooks, at least three out of four teachers believe that the textbook's objectives correspond with their educational priorities completely or fairly well. These features are widely used — 28 textbooks are used by 1300 out of a total of 1700 respondents, that is, 75 per cent of the respondents. Here again, very few (four) of the textbooks are seen as having an unsatisfactory correspondence between their objectives and teachers' priorities. Since each of these textbooks was evaluated by between five and seven teachers only, no firm conclusion is made. But, for only a few textbooks is the correspondence between their objectives and the teachers' priorities considered their most satisfactory feature.

Efforts made in recent years to increase the readability of science textbooks have, it appears, met with some success. Only nine textbooks are considered inadequate in this respect by at least 50 per cent of the users. These include the first editions of the following programs: *CHEM-Study* (two textbooks), *PSSC* (one textbook and its French translation) and *ISP* (French version of *IPS*). According to the francophone respondents, *Les chemins de la science* (the French version of *STEM*) and *La chimie: expériences et principes* are less readable than the original English-language versions. It is reasonable to suppose that the readability of the English original is difficult to preserve in translation. At present, it is hard to say whether this is the only factor that can explain such a difference.

Teachers also evaluated the activities suggested in science textbooks. Those activities contained in eight of the textbooks are considered completely or fairly adequate by at least 80 per cent of their users. These activities, however, are practically never the primary source of satisfaction. At the other extreme, the activities suggested in nine textbooks are considered marginally or not at all adequate by at least 60 per cent of their users. Curiously, this group contains seven of the 15 biology textbooks (see Appendix C for more details).

The results on the "Canadian examples" section were puzzling. In particular, two textbooks that had no Canadian content were nevertheless considered adequate in this respect. It could be that teachers consider Canadian content unimportant; in that case, they would consider textbooks satisfactory even though they contain few or even no Canadian examples. However, even though the teachers do not consider an awareness of scientific activity in Canada a very important objective, the absence of Canadian examples in the textbooks seems to trouble them. For half of the textbooks, this feature is ranked ninth or tenth (least adequate feature). It is also noteworthy that those textbooks that do contain Canadian examples are considered adequate in this regard. This is the case for *Understanding Living Things* and *ALCHEM*, for which Canadian examples represent a major source of user satisfaction.

The degree of satisfaction regarding applications of science varies, but rarely reaches a high level. On the whole, the senior-years teachers do not consider science textbooks satisfactory in this respect.

At the beginning of this section, we pointed out that the teachers are dissatisfied with the suitability of the textbooks for slow students. Generally speaking, most of the textbooks are considered very suitable for bright students, particularly at the senior-years level, where this feature is listed as the primary source of satisfaction for 13 out of 26 textbooks. However, a textbook that is adequate for bright students is often considered inadequate for slow students. Very few textbooks are considered adequate for both of these groups; amongst these exceptions are *Fundamentals of Physics* and, to a lesser extent, *STEM* and *ALCHEM*. Four textbooks are considered (by over 50 per cent) to be inadequate for bright students. Are these textbooks then adequate for slow students? The answer is "no" for two of the textbooks in question and "yes" for the other two. Since the number of respondents is small in three of the four cases, it is once again difficult to draw any firm conclusions. Nevertheless, on the whole, the science textbooks used in Canada are considered by teachers to be much more appropriate for bright students than for slow students.

Another feature which the survey respondents evaluated was the number of references to other relevant books. Since we had not specified to whom these references were to be relevant (students or teachers), the evaluation must be interpreted very generally. Fully 50 per cent or more teachers are satisfied with this feature for 24 of the 50 textbooks. Senior-years biology textbooks are considered the most adequate in this respect. Lastly, we note that these relevant references are not necessarily found in the student's textbook. For example, although one chemistry textbook, *Foundations of Chemistry*, has a 73 per cent adequacy rating with regard to relevant references, the student's text contains no such references. It must be supposed that these references are all found in the teacher's edition of the book.

The final feature evaluated by respondents is the suitability of the scientific content for the intellectual maturity of the students. According to the teachers, the great majority of the textbooks are adequate in this respect; indeed, 39 of the 50 textbooks are considered fairly or completely satisfactory by at least two-thirds of their users. This is particularly true for practically all textbooks intended for use in the senior-years level.

In conclusion, the survey indicated that the teachers are generally satisfied with their textbooks, finding them well illustrated, easy to read, and generally well suited to the intellectual maturity of their students. Teachers feel the textbooks have little to offer the slowest students but do meet the requirements of the bright students. Is it possible to develop a textbook which meets the requirements of both groups equally well? The fact that many of the textbooks do not contain Canadian examples or descriptions of science applications causes a certain amount of dissatisfaction among the teachers. And finally, the teachers consider that science textbook objectives correspond adequately to their own priorities. This finding is not too surprising, as elsewhere in the questionnaire the teachers state that they view the science textbooks as very important tools in the preparation of their lessons.

The Science Textbook Market

The Science Council's study is not primarily directed towards the problems of publishing science textbooks for use in the primary and secondary schools of Canada. Few studies have been devoted to this matter. However, figures dating from 1976 and relating to the position occupied by science textbooks in school textbook publishing are summarized in Table VI.1.

From kindergarten to grade 13, the net sales of science textbooks for the year 1976 amounted to $1 972 198. In the same year, the net sales of all school textbooks intended for these grades came to $41 962 525. Thus, science textbooks constitute 4.7 per cent of the publishing market. In terms of numbers of copies sold, the 415 218 science textbooks represent 3.6 per cent of the total 11 630 244 textbooks. One may wonder at the existence of so many different titles in such a small market. According to data provided by Statistics Canada, the volume of sales of textbooks fluctuates considerably from one year to the next. We cannot therefore infer a clear trend, either upward or downward. However, any trend, if there is one, would be important because a consistent drop in the sale of textbooks would mean that teachers are using worn-out or out-of-date books. Concerned at this possibility, the Ontario Teachers' Federation, in cooperation with the school group of the Canadian Book Publishers' Council commissioned a study on textbooks in Ontario classrooms. The author of the final report, Doris Ryan, notes that:

- about two-fifths of the books that teachers currently use in their classes were published before 1975. Slightly more than one-fifth of these books were published twelve or more years ago;
- 40 per cent of the teachers surveyed teach a class or subject in which the textbooks available for student use are out-of-date;
- among subject areas, out-of-date textbooks are in use most often by teachers of history and geography, science, and English.[4]

Table VI.1 - Sales of School Science Textbooks, 1976

Teaching Level	Copies Sold		Net Sales	
	English	French	English	French
			$	$
Early Years	81 913	43 134	370 749	192 407
Middle Years	75 774	15 712	374 916	108 586
Senior Years	172 670	26 015	772 048	153 492

Source: Statistics Canada, *Book Publishing: School Textbooks, 1976*. Cat. no. 87-603, Statistics Canada, October, 1979.

Our own survey shows that a good number of science textbooks currently in use in Canadian schools are getting old. This is of little importance for the scientific content which, as we will indicate later, is fairly standard. However, features such as avoidance of stereotypes, increased Canadian content, a social perspective and some original scientific content appear mostly in the newer textbooks (published since 1975). Deliberation over future directions for science education should take into account the aging of science textbooks.

VII. Descriptive Analysis: Aims and Methodology

The analysis of textbooks is included in the strategy of deliberative inquiry to provide a database for informing the deliberations concerning the directions of science teaching. Thus, we are not concerned with evaluating science textbooks, but rather with describing some of their significant features. Initially we examined the general properties of science textbooks, then selected certain features for more detailed study, on the basis of the general aims of the study and the specific objectives of this textbook analysis.

Selected Features of Science Textbooks

Five features of science textbooks were considered: textbooks as material objects, their science content, the structure of this content, its context, and their suggested teaching methods.

Textbooks as Material Objects

Textbooks have all the characteristics of other printed works. Their material quality can be judged by such criteria as layout, the presence of illustrations, the use of colour, legibility, readability, etc. Price, availability and country of origin may also influence the choice of a textbook. And, like any other material object, a textbook may cause different reactions in those who use it. An example of this may be the security that some parents, teachers or students feel as a result of having it in the classroom.[1]

The Science Content

Content consists of all the facts, laws and theories that constitute what may be called the rhetoric of science. Here are a few random examples from various textbooks:

> "Work is produced when a force is applied to a body and causes this body to move in the direction of motion of the force."
>
> "Mutualism is the association of two species where both species benefit from this association."
>
> "$A + B \xrightarrow{AB} AB$ and $[AB] = k \times [A] \times [B]$."
>
> "The statement that all matter consists of atoms is called the atomic theory."

The Structure of the Content

Authors can hold different opinions concerning the choice of concepts to be introduced in the course and the order of their presentation. In Table VII.1, two tables of contents from chemistry textbooks recommended for the same school years in the same province illustrate the point. Not only are the concepts presented in a different order; they are introduced in a different way. Table VII.2 illustrates two ways of introducing the concept of oxidation-reduction.

Table VII.1 – Comparison of Tables of Contents of Two Chemistry Textbooks

Textbook A[a]	Textbook B[b]
1. Chemistry, an experimental science	1. Introduction to the experimental method
2. The atomic theory	2. Mixtures, compounds and the elements
3. Principles of chemical reactions	3. Metallic and non-metallic elements
4. The gas phase: An introduction to kinetic theory	4. The behaviour of matter
5. Liquids and solids: An extension of the kinetic theory	5. The atom
6. Solutions, solubility, and ions	6. The electron universe
7. Order among atoms	7. The periodic table of elements
8. Composition of the atom and radioactivity	8. Solids
9. Electrons in atoms	9. The physical behaviour of gases
10. Chemical bonding	10. Chemical reactions and molar ratios
11. Energy in chemical and nuclear reactions	11. The liquid phase and solutions
12. The rates of chemical reactions	12. The thermal aspect of chemical reactions
13. Chemical equilibrium	13. Reaction rate

Table VII.1 – continued from previous page

Textbook A[a]	Textbook B[b]
14. Aqueous acids and bases	14. The state of equilibrium
15. Oxidation and reduction	15. Solubility, a case of equilibrium
16. The chemistry of carbon compounds	16. Acids and bases of equilibrium cases
17. Chemical bonding in gases, liquids and solids	17. Oxidation-reduction, a case of equilibrium
18. The halogens	18. Chemistry, the environment and pollution
19. The fourth row transition elements	

[a] Paul R. O'Connor *et al.*, *Chemistry: Experiments and Principles*, D.C. Heath, Toronto, p. viii.

[b] René Lahaie *et al.*, *Éléments de chimie expérimentale*, Éditions HRW, Montréal, 1976, p. v (our translation).

Table VII.2 – Two Ways of Introducing the Concept of Oxidation-Reduction

Textbook C[a]	Textbook A[b]
1. The nature of burning	1. The chemistry of electrochemical cells
2. Oxidation	2. Redox reactions in a beaker
3. Characteristics of oxygen	3. Competition for electrons
4. Activity of oxygen	4. Volts, amperes, and coulombs
5. Requirements for burning	5. The voltage of an electrochemical cell and the tendency to accept electrons
6. Oxidizing agents	6. Predicting redox reactions
7. Reduction and reducing agents	7. Storage batteries and electrochemical cells
8. Electrons and oxidation	8. Corrosion of iron, an undesirable redox reaction
9. Electrochemistry	9. The electrolysis process, a nonspontaneous redox reaction
10. Current and voltage	10. Quantitative relations in electrolysis
11. Using electrode potentials	11. Balancing oxidation-reduction equations
12. Predicting cell potentials	12. Oxidation numbers
13. Prediction of reactions between oxidizing and reducing agents	13. Review
14. Balancing redox equations	
15. Oxidation numbers	
16. Historical background	

Table VII.2 – continued from previous page

Textbook C[a]	Textbook A[b]
17. Balancing redox equations with oxidation numbers	

[a] A. Mason and C.T. Sears, *Inquiries in Chemistry*, Allyn & Bacon, Toronto, 1977, pp. 393-428.
[b] Paul R. O'Connor *et al.*, *Chemistry: Experiments and Principles*, D.C. Heath, Toronto, pp. 310-343.

Obviously, the intent is the same — to teach students how to predict the redox reaction and balance the oxidation-reduction equations properly. However, textbook C prefers to start with the combustion phenomenon (oxidation as the process of combining with oxygen), whereas textbook A uses electron transfer as the guiding thread of the chapter.

Authors may employ one or more of the following criteria to structure content:

- the historical sequence of the growth of knowledge;
- the logical order of a modern reconstruction of a discipline (the structure of a discipline);
- a hierarchical model of learning;
- the cognitive level of the student and his prescientific ideas;
- the desire to present scientific activity from different points of view (cultural, social, technological, etc.);
- the aim of the course (preparation for higher studies or general education);
- force of habit (standardization of textbooks).

The Context of the Science Content

Authors enjoy considerable latitude in choosing the context in which they present the science content. The context may be defined briefly as the sum of all the information not included in the science content as described above. For the purposes of the study we identified four components of this context.

1. Messages about science: The author states his concept of the nature of science. This is the "rhetoric *about* science." Consciously or otherwise, the author adopts one or more philosophical points of view. Here are some examples:

> "In this book you will see some examples of rules in science that have been shown to be wrong. They have been replaced by new rules. Someday these new rules may have to be changed too. This method of trying to create explanations that fit all the facts has led to such wonderful successes as polio vaccine and the propulsion of rockets to the moon."[2]
>
> "What can we do while we wait for science and technology to discover the new sources of energy we so desperately need?"[3]

> "It is characteristic of today's researchers that they accept the obligation to publish their results world-wide through the medium of specialized periodicals and congresses, so that their colleagues can discuss them and profit from them in the interest of hastening new discoveries."[4]

2. The physical component: This component represents the physical framework (or the absence of one) in which an author chooses to set the subject matter. The following example shows how a piece of scientific information can be imparted without any distinct framework:

> "*Effect of pH:* The action of all enzymes is influenced by the pH of the solution in which they are operating. For every enzyme there is an *optimal pH* at which the rate of reaction is at its maximum. If there is a departure from this pH in either direction the rate of reaction decreases rapidly and soon reaches zero. Again, the explanation lies in the denaturation of the enzyme at pH values some distance away from the optimal."[5]

Here is an example where a physical context is present:

> "A much better way to prevent corrosion of iron involves bringing a stronger reducing agent than iron into the system. A metal such as zinc or magnesium in close contact with iron becomes the anode, forcing iron to act as a cathode. The zinc or magnesium piece is oxidized, releasing electrons. The iron bar does not corrode. Ship hulls are protected in this fashion. Large blocks of zinc metal are bolted to the steel hulls. The zinc oxidizes, largely preventing loss of iron from the hull."[6]

Authors describe physical contexts in several ways, using photographs, maps, diagrams, etc.

3. The historical component: We defined the historical component as the sum total of information concerning the history of science and technology, including relevant social and cultural considerations. This component contributes to the historical "depth" with which the author endows his work.

4. The sociocultural component: This component comprises the following elements that are situated on the periphery of scientific activity:

- information on technological processes and products and their links with science;
- the social impact of science and technology;
- the economic and political aspects of science and technology;
- ethical and legal considerations;
- information about careers in science and technology.

The presence of a context, or more accurately of a "contextual web" depends both on the aims of science teaching and on the author's intentions. This relationship is emphasized by one of us (G.O.) specifically in reference to the Canadian context, but the line of reasoning applies also to other aspects of the sociocultural content.

"One of the consequences of choosing new goals for any enterprise is that, in the process, other goals, equally legitimate in principle, are inevitably discarded. In this case, goals concerned with the relevance of science to issues of personal, social, and national importance were down-rated in favour of those concerned with the 'structure of the discipline.' And goals embodying such notions as the 'processes of inquiry' in particular transcend national boundaries; they are essentially universal in their nature. Given a commitment to such goals, references to Canada, Canadians, and Canadian issues become not only unnecessary; they may even be distractions from the overall direction of the curriculum."[7]

The existence of a particular context may also be justified by various pedagogical objectives. Thomas Russell has this to say about the historical context:

"Why, then, do we teach the history of science? As noted earlier, arguments have been advanced on two main fronts in the 1955-1975 period. Some seek to improve student interest in and appreciation of science; others seek to have students understand the methods of science."[8]

Contextual analysis of a science textbook, therefore, cannot be divorced from the aims for science education prevailing at the time these textbooks are in use.

Pedagogy

The difference between a school textbook and any other printed work containing the same information lies in its educational purpose. A textbook is a teaching tool. As such, it must therefore incorporate instructional strategies designed to create learning situations for students. These strategies usually take the following forms:

- questions included in the text with varying style, frequency and placement;
- questions, exercises and problems of application, generally placed at the end of a chapter;
- practical activities to be carried out in the laboratory, outlined either in the textbook or in a separate laboratory manual;
- less frequently, a series of projects to be undertaken outside the school.

These strategies are intended to make it possible for the student to attain the general aims of science education — the acquisition of factual knowledge, skills and a set of desirable attitudes.

Which strategies authors choose depend on their educational ideals, their view of the world and of science in particular and their theories of teaching and learning.

Goals and Limitations of the Textbook Analysis

This analysis was intended to help us answer two questions:

- to what extent do the content and suggested activities of science textbooks enable students to reach the overall aims of science education?
- to what extent are contemporary criticisms of science education applicable to the textbooks currently in use?

The selection of aims is based on the results of the analysis of ministry guidelines. For all provinces and territories the most common aims are those associated with science content, the acquisition of scientific skills and the development of an awareness of the relationship between science and society. Since we decided not to examine the science content of courses or textbooks, it is not referred to here. The analysis followed the general aims of the study, focussing primarily on the context in which the science content is presented and on what students may learn from this context. The selection of criticisms is based on those outlined in chapter I of this study.

In summary, we selected the following aims for analysis purposes:

- acquisition of scientific skills;
- the science-technology-society interaction.

Of the issues raised by criticisms of science education we selected the following:

- the Canadian context of science education;
- images of science conveyed by textbooks;
- attitudes towards careers in science and technology.

Finally, an examination of the stated aims of textbooks enabled us to get a general — though still incomplete — idea of the educational priorities of authors.

Methodology

The textbook analysis revolved around six themes: the stated aims of science textbooks, the acquisition of scientific skills, a growing understanding of the interaction between science, technology and society, the Canadian context in science teaching, the image of scientific activity conveyed by science textbooks and the encouragement to pursue careers in science and engineering.* Appendix D contains original analytical schemes for five of these themes. For the sixth, we used an instrument developed by M. Fuhrman, V. Lunetta, S. Novick and P. Tamir,[9] whereby the practical activities specified in the laboratory manual for students to undertake in laboratory classes can be classified according to their degree of complexity. These six analytical schemes were appraised by independent experts and tested before being used for the analysis itself.

* The data collected concerning careers was insufficient for a complete section in this report. The relevant information has therefore been integrated with other analyses.

We used the results of the survey of science teachers to draw up a list of textbooks to be analyzed. Two criteria were used to select each textbook to be analyzed: the number of teachers mentioning its use in their classes and the number of provinces in which it is used to a significant extent. Geographical and linguistic considerations were also taken into account. Table VII.3 indicates the distribution of textbooks selected for analysis and Table VII.4 provides a complete list.

Table VII.3 – Number and Distribution of Textbooks Analyzed, by Grade Level, Subject and Language

Subject	General Science		Physical Sciences		Biology Ecology		Chemistry		Physics		Total	
	E	F	E	F	E	F	E	F	E	F	E	F
Early Years	2	2									2	2
Middle Years	3	0	2	2	4	3					9	5
Senior Years					5	0	5	1	3	1	13	2

Note: E: English, F: French

Table VII.4 – Textbooks Analyzed

Early Years

01. *Les Chemins de la science*, Verne N. Rockcastle *et al.*, translated and adapted by Fernand Séguin, Éditions du renouveau pédagogique, 1978 (volume 5).

02. *Les Chemins de la science*, Verne N. Rockcastle *et al.*, translated and adapted by Fernand Séguin, Éditions du renouveau pédagogique, 1978 (volume 6).

03. *Laidlaw Exploring Science Program*, Milo K. Blecha *et al.*, Doubleday Canada Ltd., 1977 (Red Book, Grade 6).

04. *Space, Time, Energy, Matter (STEM)*, Verne N. Rockcastle *et al.*, Addison-Wesley, 1977 (grade 5).

Middle Years

Biology

11. *Biological Sciences: An Introductory Study*, William Andrews *et al.*, Prentice-Hall, 1980.

12. *Biologie humaine*, Charles Désiré *et al.*, Centre Éducatif et Culturel, 1968.

13. *Les êtres et leur milieu*, M. Poirier *et al.*, Brault et Bouthillier, 1970.

14. *Focus on Life Science*, C.H. Heimler and J.D. Lockard, Charles Merrill, 1977.

15. *Focus on Science: Exploring the Natural World*, Doug Gough and Frank Flanagan, D.C. Heath, 1980.

16. *Introduction à la biologie: perspective écologique*, Paul Thibeault et R. D'Aoust, Éditions Hurtubise HMH, 1970.

17. *Life Science: A Problem Solving Approach*, Joseph L. Carter *et al.*, Ginn, 1974.

Table VII.4 – Continued from previous page

Physical Science

21. *Exploring Matter and Energy*, Milo K. Blecha *et al.*, Doubleday Canada, 1978.

22. *Initiation aux sciences physiques*, U. Haber-Schaim *et al.*, translated and adapted by J.M. Chevrier, Institut de recherches psychologiques, 1969.

23. *Physical Science: An Introductory Study*, William Andrews *et al.*, Prentice-Hall, 1978.

24. *Science physiques: Matière, énergie, interactions*, R.R. McNaughton and R.W. Heath, translated and adapted by J. Bergeron and M. Mercure, Centre Éducatif et Culturel, 1977.

General Science

31. *Developing Science Concepts in the Laboratory*, M.C. Schmid and M.T. Murphy, Prentice-Hall, 1979.

32. *Introducing Science Concepts in the Laboratory*, M.C. Schmid and M.T. Murphy, Prentice-Hall, 1977.

33. *Scienceways*, (Blue Level), John McBean *et al.*, Copp Clark Pitman, 1979.

Senior Years

Biology

41. *Biological Science: An Ecological Approach* (BSCS Green), Biological Sciences Curriculum Study, Rand McNally, 1978.

42. *Biology* J.W. Kimball *et al.*, Addison-Wesley, 1978.

43. *Modern Biology*, J.J. Otto and Albert Towle, Holt, Rinehart & Winston, 1969.

44. *Understanding Living Things*, John Reimer and W. Wilson, D.C. Heath, 1977.

Chemistry

51. *ALCHEM*, Frank Jenkins *et al.*, J.M. LeBel, 1978.

51a. *ALCHEM Elective:* Ethylene and Its Derivatives, Frank Jenkins *et al.*, J.M. LeBel, 1979.

51b. *ALCHEM Elective*: Solar Energy, Solar Education for the 80's, Frank Jenkins *et al.*, J.M. LeBel, 1980.

52. *Chemistry Today*, R.L. Whitman and E.E. Zinck, Prentice-Hall, 1976.

53. *Chemistry: Experimental Foundations*, Robert W. Parry *et al.*, Prentice-Hall, 1975.

54. *Chemistry: Experiments and Principles*, Paul R. O'Connor *et al.*, D.C. Heath, 1977.

55. *Éléments de chimie expérimentale*, René Lahaie *et al.*, Holt, Rinehart & Winston, 1976.

56. *Keys to Chemistry*, E. Ledbetter and J. Young, Addison-Wesley, 1977.

Physics

61. *Fundamentals of Physics*, R.W. Heath *et al.*, D.C. Heath, 1979.

62. *Matter and Energy*, J.H. MacLachlan *et al.*, Clarke, Irwin, 1977.

63. *Physics (PSSC)*, U. Haber-Schaim *et al.*, D.C. Heath, 1965.

64. *Les sciences par objectifs de comportement: physique*, Le groupe SO_2, Éditions du Renouveau Pédagogique, 1974.

The task of examining such a large number of textbooks, intended for different populations, from so many different viewpoints, far surpassed the capacity of any single individual. For this reason, Council appointed a team of 18 science education specialists who, following an intensive training period, examined the textbooks from April to June of 1982. The detailed technical reports of each analyst will be rearranged and published later. Chapter VIII offers a synthesis of the results. The analysis is descriptive — the researchers made no evaluative judgements. Rather they raised a series of questions, suggested by the data, for discussion at the deliberative conferences.

VIII. Descriptive Analysis: Results

This chapter provides a general view of certain features of the textbooks used in Canadian schools, arranged by the three teaching levels used in the study. It is not a comparative analysis, and the discussions and questions are less concerned with individual books than with the group of the most frequently used science textbooks.

The results are presented in tabular form in order to give the reader the primary data on which our discussions are based. This format facilitates reading of the data and ready identification of trends. Each section of the analysis is accompanied by questions for deliberation.

Table VII.4 (see p. 94) lists the titles of the textbooks that were analyzed. To simplify the tables in this chapter, each book is referred to by its code number, which is also used in both discussion and questions.

Stated Aims of Science Textbooks

Authors express their intentions in various ways. Sometimes, these are addressed to the student, at other times to the teacher. Some are worded according to norms for the construction of behavioural objectives, while others are worded very vaguely. In order to express this diversity clearly we have used the following symbols:

X - the authors suggest one or more general aims in a given category;

O - the authors suggest one or more specific aims (generally in the form of a behavioural objective) in a given category;

? - the authors indicate a partial, limited, or vague intention in a given category.

The categories of aims correspond to those used elsewhere in the study (see chapter V). Table VIII.1a-b shows aims stated by science textbook authors, listed by textbook and category of aim.

Table VIII.1a – Aims of Science Textbooks

Early Years (00); Middle Years, Biology (10), Physical Science (20), General Science (30)

Textbook code	01	02	03	04	11	12	13	14	15	16	17	21	22	23	24	31	32	33
Science Content	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Scientific Skills/Processes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Science and Society	0	X	X	0	X	0	X	X	X	X		X		X	X	X	X	X
Nature of Science	X	X		X	?	0		X	X		?	0	X	?		X	X	
Personal Growth	X	X	X	X	X	X	X		X	X	X		X		X	X	X	X
Science-Related Attitudes			X		X					X		X		X	X		?	X
Applied Science and Technology	0	0		0				?	X			X		0				0
Career Opportunities			X	X			X	X	?			X						

Practically all the textbooks contain aims associated with the acquisition of science content and scientific process skills. This is not surprising. With regard to these two categories at least, ministries of education and the authors of textbooks have the same aims. With regard to the third category, science and society, 28 of the 34 textbooks in our sample state this as one of their aims. Ministry guidelines — at least at the middle years — also contain aims relating to the interaction between science, technology and society. Of the 14 textbooks intended for this level, 12 state aims belonging to this category. Interestingly, the two textbooks stating no science and society aims (textbooks 17 and 22) contain an emphasis on the discovery of scientific concepts. Like other textbooks of this kind, such a context often contains very few or no messages other than those concerning the nature of science.

The number of stated aims belonging to the fourth category, the nature of science and the history of science and technology, is also high; however, some of these aims are not very clearly stated. Aims relating to the history of science alone are very few, but the history of science is not necessarily ignored when there is no stated intention regarding it.

According to their authors, science textbooks are intended to contribute to the personal growth of students. A few examples illustrate the confidence and optimism of certain authors in this area. The authors' intentions vary greatly, ranging from the development of democratic attitudes and behaviour (61) to the development in students of a healthy scepticism that takes account of the opinions of others and encourages them to have confidence in their own views (02), thus building independence and self-confidence (56).

Less than half the textbooks contain aims relating to the students' attitudes towards science. These aims generally have to do with those characteristics that one would like to see students develop: an interest in science, excitement, stimulation and so on. In certain textbooks, however, the wording of aims in this category was puzzling:

- to furnish a base for the development of positive values and attitudes vis-à-vis science in everyday life (03);
- to develop a positive attitude towards science and a lively interest in its various aspects (21).

The concern we felt is derived from an impression of manipulation that appears implicit in the wording of these aims. Even when the authors of the second example develop their point with suggestions for students to participate in a young scientists' club or in science fairs, the idea of a positive attitude towards science, and also the means of measuring it, remain far from clear.

Textbook authors do not generally regard the study of applied science and technology as being important. While the majority of physics and chemistry textbooks mention applications of science here and there, only a few of them consider applied science and technology a sufficiently important subject of study to justify stating an aim for it. In

Table VIII.1b — Aims of Science Textbooks

Senior Years, Biology (40), Chemistry (50), Physics (60)

Textbook code	41	42	43	44	51	51a	51b	52	53	54	55	56	61	62	63	64
Science Content	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0
Scientific Skills/Processes	X	X		X	X		X	X	X	X	X	X	X	X	X	0
Science and Society	X		X	0		X	X	X	X	X	X	X	X		X	
Nature of Science	X	X		X			?	X	X	X	X	X	X	X	X	0
Personal Growth	X	X		X			X		X	X	X	X	X	X	X	
Science-Related Attitudes									X	X		X	X	X	?	
Applied Science and Technology				0	X	X	X	0	?	X	0	X	X	0	?	0
Career Opportunities	X											?	X		?	

fact, only *ALCHEM* (51) explicitly emphasizes the growing importance of the applied sciences. As well, two optional supplements of the *ALCHEM* program are concerned primarily with applied science: ethylene and its derivatives (51a), and solar energy (51b). We also noted that aims in this category are worded in ways that almost always stress pure science and its applications, and rarely the technological phenomena and their comprehension.

According to the authors of science textbooks, encouraging students to consider careers in science is not an important aim either. Only a few textbooks state this as a specific intention and we shall explain later how this intention is translated into concrete terms.

At first sight, therefore, the variety of aims stated by science textbook authors shows the same diversity and optimism as ministry guidelines. In this sense, the questions we asked at the conclusion of that analysis (see chapter V, p. 60) are still pertinent. However, examining textbooks enables us to get a better idea of authors' priorities. If one looks at lists of behavioural objectives (the abundance of which, since the start of the 1970s, is truly astounding), it is interesting to compare the number of aims relating to science content and scientific processes with the number of aims in other categories (see Table VIII.2).

Table VIII.2 – Examples of the Relative Importance of Textbook Aims

Textbook code number	02	21	44	55	61
Number of aims relating to the acquisition of content and scientific processes	167	97	95	419	29
Number of aims relating to the social implications of scientific and technological activity	5	31	5	15	4

This still provides only a partial picture. With respect to the total number of aims, some authors appear more specific than others. Moreover, the information and activities designed to give concrete expression to the aims relating to the interaction among science, technology and society are situated, in at least three out of the five textbooks taken as examples, in the very last chapters of the book. These chapters tend to be less systematically studied than the earlier ones.

Although this study of the explicit intentions of science textbooks identifies their priorities, it furnishes only a partial picture which the rest of this analysis must supplement. The aims are expressed in many different ways and breaking up general aims into a number of very specific behavioural objectives is a strong trend. While the aims that relate to science content and scientific processes seem to lend themselves to such fragmentation, we may well ask ourselves whether those belonging to other categories, such as the development of attitudes or values, are equally amenable to such a process, and, if so, how this can be done.

Secondly, the intentions of the textbooks are addressed sometimes to teachers, sometimes to students and sometimes to both with no apparent reason for the difference. No doubt students and their parents would like to know the nature and extent of the preparations for later life that a particular textbook offers.

Finally, as with the analysis of ministry guidelines, the issues raised by our discussion papers do not seem to be among the priorities of science textbook authors. The *ALCHEM* program is one exception. Its authors emphasize that it is in line with the recommendations of the Symons Report concerning a Canadian context in science textbooks. However, the point of view of the engineer, advocated by Donald George, is, for all practical purposes, absent from textbooks. Only textbook 21 devotes a few pages to the engineer's art. Even it, however, defines engineering as follows:

> "Engineering is the changing of scientific discoveries into technology. Or, to state it another way, it is putting science to use in making new things or providing new services."[1]

Clearly, this textbook ranks the engineer below the scientist — a point of view which is implicit in the other textbooks we examined. The engineering perspective, however, is systematically dealt with in the booklets of the *ALCHEM* program.

Although the special needs of girls with regard to scientific training are rarely the subject of an author's stated intentions, textbooks have slowly but surely evolved towards eliminating the crudest sex stereotypes. This follows both ministry guidelines and publishers' own policies.[2,3] In general, illustrations are modified to show more girls or women, and, where possible, in nonstereotyped roles. Also, certain passages are amended to take girls into account. For example, in the first edition of the *PSSC Physics* textbook, only boys jumped, spun around and rode in wagons to illustrate the laws of dynamics. In the latest edition, girls are doing the same thing.[4]

One physical science textbook (21) discusses scientific careers in detail. While the rest of this textbook depicts roughly equal numbers of boys and girls in the illustrations, those in the section on scientific careers are almost all of men. On one hand, this may represent a reality — the underrepresentation of women in science and technology. On the other hand, it leads one to wonder about the impact of implicit messages conveyed by such illustrations.

This examination of the stated aims of science textbooks needs to be complemented by a description of the means provided by authors for achieving some of their aims. That is the subject of the next part of this report.

Scientific Skills in the Laboratory

The laboratory manual, or the section of the textbook that contains instructions for laboratory work, plays an important part in providing for aims relating to the acquisition of scientific process skills. The laboratory is the place where the student can acquire these skills, this scientific know-how, by working directly with materials.

We studied the kinds of tasks demanded of students in the laboratory in order to determine what sort of skills a student might acquire and to see to what extent the textbook was helping students in this respect. We used an instrument developed by M. Fuhrman *et al.*[5], after consulting a number of articles on the subject.[6,7,8] However, unlike the originators of this instrument, who systematically analyzed all the experiments suggested in one manual, we analyzed only those experiments usually carried out during a school year. The latter figure is often much smaller than the former but it is more realistic. In order to construct an equivalent sampling of experiments each analyst contacted a teacher who was using the manual in question. In some cases, the analysts obtained the number and names of the experiments actually completed; in others, they only obtained the number and had to exercise their own judgement to construct the sample. Although we realized that two teachers using the same manual were not necessarily giving the same set of experiments, we also assumed that, if all the experiments involve similar tasks, similar conditions for developing the same skills would be provided. Otherwise, skills that are different in kind or degree may be developed. In view of these difficulties, the results can at best only indicate trends. However, we consider that these trends are themselves interesting.

Table VIII.3a-e presents the results of our analysis of laboratory activities. Again a code number identifies each textbook (see Table VII.4). The figures in the table represent the percentage of experiments in which the task in question is demanded of the student at least once.

Table VIII.3a – Structure and Task Analysis of Laboratory Work – Early Years (00) – percentages

Textbook code	01	02	03	04
Number of experiments analyzed	49	50	38	49
Structure				
a.1 High structure	76	88	97	98
a.2 Low structure	24	12	3	2
a.3 Inductive approach	82	84	87	98
a.4 Deductive approach	18	26	13	2
Cooperative mode				
b.1 Students work on a common task and pool results	18	6	0	12
b.2 Students work on different tasks and pool results	10	4	0	0
b.3 Postlab discussion required	0	14	0	4

Table VIII.3a – continued from previous page

Textbook code	01	02	03	04
Number of experiments analyzed	49	50	38	49
Task categories				
1.0 Planning and Design				
1.1 Formulates a question or defines a problem to be investigated	0	0	0	0
1.2 Predicts experimental result	22	2	13	14
1.3 Formulates hypothesis to be tested in this investigation	4	18	0	0
1.4 Designs observation or measurement procedure	10	6	0	2
1.5 Designs experiment	2	12	0	0
2.0 Performance				
2.1a Carries out qualitative observation	90	86	90	84
2.1b Carries out quantitative observation or measurement	34	40	24	18
2.2 Manipulates apparatus; develops technique	63	66	13	47
2.3 Records result, describes observation	33	12	26	22
2.4 Performs numeric calculation	2	14	5	4
2.5 Interprets, explains or makes a decision about experimental technique	14	18	3	2
2.6 Works according to own design	2	12	0	0
3.0 Analysis and Interpretation				
3.1a Transforms result into standard form (other than graphs)	4	2	13	6
3.1b Graphs data	2	2	0	0
3.2a Determines qualitative relationship	82	38	61	74
3.2b Determines quantitative relationship	21	22	18	18
3.3 Determines accuracy of experimental data	0	4	0	0
3.4 Defines or discusses the limitations or assumptions that underlie the experiment	4	24	0	0
3.5 Formulates or proposes a generalization or model	8	12	16	4
3.6 Explains a relationship	25	16	50	29
3.7 Formulates new questions or defines problem based upon the results of investigation	0	0	0	0

Table VIII.3a – continued from previous page

Textbook code	01	02	03	04
Number of experiments analyzed	49	50	38	49
4.0 Application				
4.1 Predicts based upon the results of this investigation	8	12	26	27
4.2 Formulates hypothesis based upon the results of this investigation	2	34	8	0
4.3 Applies experimental technique to new problem or variable	0	18	3	0

Table VIII.3b – Structure and Task Analysis of Laboratory Work – Middle Years, Biology (10) – percentages

Textbook code	11	12	13	14	15	16	17
Number of experiments analyzed	20	18	49	107	18	19	20
Structure							
a.1 High structure	100	83	100	94	78	79	100
a.2 Low structure	0	17	0	6	22	21	0
a.3 Inductive approach	30	0	57	95	39	21	100
a.4 Deductive approach	50	100	61	5	11	79	0
Cooperative mode							
b.1 Students work on a common task and pool results	0	0	0	18	6	0	0
b.2 Students work on different tasks and pool results	0	0	4	0	0	0	0
b.3 Postlab discussion required	0	0	4	2	0	0	100
Task categories							
1.0 Planning and Design							
1.1 Formulates a question or defines a problem to be investigated	0	0	0	0	0	0	20
1.2 Predicts experimental result	5	0	2	0	0	0	5
1.3 Formulates hypothesis to be tested in this investigation	0	0	6	0	0	11	5
1.4 Designs observation or measurement procedure	0	0	2	0	6	0	5
1.5 Designs experiment	0	0	0	0	0	0	15

Table VIII.3b – continued from previous page

Textbook code		11	12	13	14	15	16	17
Number of experiments analyzed		20	18	49	107	18	19	20
2.0	*Performance*							
2.1a	Carries out qualitative observation	75	83	80	73	100	90	75
2.1b	Carries out quantitative observation or measurement	35	0	51	26	28	47	30
2.2	Manipulates apparatus; develops technique	80	33	84	47	83	32	85
2.3	Records result, describes observation	85	67	67	26	83	11	75
2.4	Performs numeric calculation	30	0	22	10	0	5	30
2.5	Interprets, explains or makes a decision about experimental technique	10	0	12	36	33	5	30
2.6	Works according to own design	5	0	2	0	6	0	20
3.0	*Analysis and Interpretation*							
3.1a	Transforms result into standard form (other than graphs)	65	44	33	15	61	42	0
3.1b	Graphs data	5	0	8	2	0	5	10
3.2a	Determines qualitative relationship	50	44	16	29	44	53	40
3.2b	Determines quantitative relationship	25	0	14	11	0	26	30
3.3	Determines accuracy of experimental data	0	0	0	0	0	0	0
3.4	Defines or discusses the limitations or assumptions that underlie the experiment	5	0	2	3	0	5	5
3.5	Formulates or proposes a generalization or model	10	0	0	29	17	0	10
3.6	Explains a relationship	50	22	2	37	33	5	20
3.7	Formulates new questions or defines problem based upon the results of investigation	0	0	0	0	0	0	0

Table VIII.3b – continued from previous page

Textbook code		11	12	13	14	15	16	17
Number of experiments analyzed		20	18	49	107	18	19	20
4.0	*Application*							
4.1	Predicts based upon the results of this investigation	40	0	0	7	33	0	20
4.2	Formulates hypothesis based upon the results of this investigation	15	0	4	36	50	0	25
4.3	Applies experimental technique to new problem or variable	15	0	10	1	6	0	10

Table VIII.3c – Structure and Task Analysis of Laboratory Work – Middle Years, Physical Sciences (20) and General Science (30) – percentages

Textbook code		21	22	23	24	31	32	33
Number of experiments analyzed		24	43	24	22	58	33	18
Structure								
a.1	High structure	100	86	100	0	100	100	72
a.2	Low structure	0	14	0	0	0	0	28
a.3	Inductive approach	25	70	42	95	98	0	39
a.4	Deductive approach	75	30	42	0	2	100	17
Cooperative mode								
b.1	Students work on a common task and pool results	0	16	17	0	16	6	0
b.2	Students work on different tasks and pool results	0	2	0	0	0	3	0
b.3	Postlab discussion required	8	2	38	0	0	0	0
Task categories								
1.0	*Planning and Design*							
1.1	Formulates a question or defines a problem to be investigated	0	0	0	0	0	0	39
1.2	Predicts experimental result	0	21	13	0	5	12	6
1.3	Formulates hypothesis to be tested in this investigation	0	7	4	5	0	0	6
1.4	Designs observation or measurement procedure	0	5	13	0	0	3	17
1.5	Designs experiment	4	0	0	0	0	0	6

Table VIII.3c – continued from previous page

Textbook code		21	22	23	24	31	32	33
Number of experiments analyzed		24	43	24	22	58	33	18
2.0	*Performance*							
2.1a	Carries out qualitative observation	92	67	42	100	85	91	56
2.1b	Carries out quantitative observation or measurement	4	72	58	64	52	49	56
2.2	Manipulates apparatus; develops technique	46	91	79	27	85	88	95
2.3	Records result, describes observation	21	40	92	100	98	91	89
2.4	Performs numeric calculation	4	42	38	50	36	6	17
2.5	Interprets, explains or makes a decision about experimental technique	0	26	13	5	85	9	17
2.6	Works according to own design	0	2	4	0	0	0	11
3.0	*Analysis and Interpretation*							
3.1a	Transforms result into standard form (other than graphs)	17	2	17	5	31	6	72
3.1b	Graphs data	4	7	29	18	5	6	11
3.2a	Determines qualitative relationship	42	54	25	100	74	79	11
3.2b	Determines quantitative relationship	4	56	21	68	48	36	39
3.3	Determines accuracy of experimental data	0	7	0	5	0	0	0
3.4	Defines or discusses the limitations or assumptions that underlie the experiment	0	9	8	50	0	3	44
3.5	Formulates or proposes a generalization or model	4	14	8	27	93	9	17
3.6	Explains a relationship	25	21	29	36	40	52	6
3.7	Formulates new questions or defines problem based upon the results of investigation	0	2	0	36	2	0	0

Table VIII.3c – continued from previous page							
Textbook code	21	22	23	24	31	32	33
Number of experiments analyzed	24	43	24	22	58	33	18
4.0 Application							
4.1 Predicts based upon the results of this investigation	4	5	4	64	95	73	33
4.2 Formulates hypothesis based upon the results of this investigation	0	7	4	41	0	3	17
4.3 Applies experimental technique to new problem or variable	0	2	0	9	0	18	6

Table VIII.3d – Structure and Task Analysis of Laboratory Work – Senior Years, Chemistry (50) – percentages

Textbook code	51	52	53	54	55	56
Number of experiments analyzed	11	14	19	23	24	31
Structure						
a.1 High structure	100	100	95	78	96	87
a.2 Low structure	0	0	5	22	4	16
a.3 Inductive approach	9	93	58	83	21	58
a.4 Deductive approach	36	7	47	17	91	48
Cooperative mode						
b.1 Students work on a common task and pool results	0	0	11	9	0	0
b.2 Students work on different tasks and pool results	0	7	21	0	0	3
b.3 Postlab discussion required	9	93	100	57	4	0
Task categories						
1.0 Planning and Design						
1.1 Formulates a question or defines a problem to be investigated	0	0	0	0	0	0
1.2 Predicts experimental result	36	7	5	4	0	3
1.3 Formulates hypothesis to be tested in this investigation	0	0	0	4	0	0
1.4 Designs observation or measurement procedure	0	0	0	13	4	13
1.5 Designs experiment	0	0	0	4	0	0

Table VIII.3d – continued from previous page							
Textbook code		51	52	53	54	55	56
Number of experiments analyzed		11	14	19	23	24	31
2.0	*Performance*						
2.1a	Carries out qualitative observation	91	64	79	100	83	84
2.1b	Carries out quantitative observation or measurement	55	43	63	57	58	55
2.2	Manipulates apparatus; develops technique	91	86	68	70	79	84
2.3	Records result, describes observation	73	93	90	96	92	100
2.4	Performs numeric calculation	36	43	42	39	25	19
2.5	Interprets, explains or makes a decision about experimental technique	9	50	21	48	8	16
2.6	Works according to own design	0	0	0	9	4	16
3.0	*Analysis and Interpretation*						
3.1a	Transforms result into standard form (other than graphs)	36	43	21	22	63	48
3.1b	Graphs data	0	14	11	9	13	16
3.2a	Determines qualitative relationship	27	21	42	44	58	68
3.2b	Determines quantitative relationship	18	50	42	44	58	16
3.3	Determines accuracy of experimental data	0	29	26	4	0	3
3.4	Defines or discusses limitations or assumptions that underlie the experiment	0	7	5	17	0	3
3.5	Formulates or proposes a generalization or model	9	21	21	52	25	29
3.6	Explains a relationship	18	7	53	35	13	29
3.7	Formulates new questions or defines problem based upon the results of investigation	0	21	0	17	0	3
4.0	*Application*						
4.1	Predicts based upon the results of this investigation	18	50	37	44	38	29

Table VIII.3d – continued from previous page

Textbook code		51	52	53	54	55	56
Number of experiments analyzed		11	14	19	23	24	31
4.2	Formulates hypothesis based upon the results of this investigation	0	7	26	9	8	26
4.3	Applies experimental technique to new problem or variable	0	14	5	17	0	10

Table VIII.3e – Structure and Task Analysis of Laboratory Work – Senior Years, Biology (40) and Physics (60) – percentages

Textbook code		41	42	43	44	61	62	63	64
Number of experiments analyzed		24	20	67	27	58	60	25	21
Structure									
a.1	High structure	100	100	98	89	100	100	100	0
a.2	Low structure	0	0	2	11	0	0	0	0
a.3	Inductive approach	96	30	39	78	98	93	0	57
a.4	Deductive approach	4	70	61	44	2	15	100	15
Cooperative mode									
b.1	Students work on a common task and pool results	29	10	6	30	2	3	0	0
b.2	Students work on different tasks and pool results	8	0	0	11	0	0	0	5
b.3	Postlab discussion required	83	0	0	26	0	0	16	0
Task categories									
1.0	*Planning and Design*								
1.1	Formulates a question or defines a problem to be investigated	4	0	0	15	0	0	0	0
1.2	Predicts experimental result	13	0	0	26	2	0	68	0
1.3	Formulates hypothesis to be tested in this investigation	33	0	0	41	0	0	4	0
1.4	Designs observation or measurement procedure	8	0	0	37	0	2	4	0
1.5	Designs experiment	8	0	0	15	0	0	0	5
2.0	*Performance*								
2.1a	Carries out qualitative observation	75	90	79	85	72	53	16	100
2.1b	Carries out quantitative observation or measurement	46	60	21	59	52	65	84	81

Table VIII.3e – continued from previous page

Textbook code		41	42	43	44	61	62	63	64
Number of experiments analyzed		24	20	67	27	58	60	25	21
2.2	Manipulates apparatus; develops technique	71	85	81	63	100	100	92	100
2.3	Records result, describes observation	79	80	85	74	100	100	96	100
2.4	Performs numeric calculation	33	30	8	52	48	37	76	76
2.5	Interprets, explains or makes a decision about experimental technique	58	10	15	59	5	2	28	38
2.6	Works according to own design	8	0	3	19	0	0	0	5
3.0	*Analysis and Interpretation*								
3.1a	Transforms result into standard form (other than graphs)	29	60	69	33	27	0	72	62
3.1b	Graphs data	25	15	5	16	16	10	36	38
3.2a	Determines qualitative relationship	67	75	25	82	55	50	36	100
3.2b	Determines quantitative relationship	42	50	22	52	38	50	80	71
3.3	Determines accuracy of experimental data	0	5	0	15	10	5	12	24
3.4	Defines or discusses limitations or assumptions that underlie the experiment	58	10	2	59	9	7	24	24
3.5	Formulates or proposes a generalization or model	50	40	12	37	38	52	44	38
3.6	Explains a relationship	88	45	45	78	17	23	44	62
3.7	Formulates new questions or defines problem based upon the results of investigation	21	5	0	15	0	2	52	0
4.0	*Application*								
4.1	Predicts based upon the results of this investigation	67	30	8	44	24	28	40	14
4.2	Formulates hypothesis based upon the results of this investigation	92	0	3	44	7	3	4	19
4.3	Applies experimental technique to new problem or variable	0	0	76	4	3	2	4	0

The data in Table VIII.3 point to two sets of conclusions. The first set concerns the structure of the laboratory exercises. The figures show that laboratory exercises are almost always highly structured. In both the middle and senior years, in only one instance (out of 28) does the proportion of relatively less-structured experiments exceed 25 per cent of the total. Of the 28 textbooks examined, 18 contain experiments, 95 per cent of which are highly structured. A further question concerns the approach chosen for the experiments. Are students encouraged to make generalizations from the information collected (the inductive approach) or must they verify laws previously learned in class (the deductive approach)? While the inductive approach is more popular for the early years (for obvious reasons), this is not the case in the later years. And, while most textbooks suggest both approaches, some of them clearly favour one or the other. In terms of the aims chosen for science education, one approach may be more appropriate than the other. The question then is whether this affects the choice of textbooks. Finally, at all three levels, students are neither frequently nor strongly encouraged to work together during laboratory work or to share results.

The second set of conclusions relates to what students really do in the laboratory, assuming that both teachers and students follow the directions in the laboratory manuals. It is striking to note that out of 32 textbooks examined, 28 of them never ask the student to formulate a question or define a problem to be solved, and the student is only rarely asked to plan the observation or measurement procedure, to determine the accuracy of the results, and even more rarely to plan the experiment. Only three books in our sample contain such directions. On the other hand, students are very often asked to observe, to use apparatus or apply techniques, to establish relationships and to compile the results. In the senior years, they are asked somewhat more often to explain relationships and formulas or to suggest a generalization or model, but even then, this rarely occurs in more than half the experiments. Moreover, students are seldom invited to make predictions from the results of the investigation in more than half the total number of experiments we examined. Finally, students have almost no opportunity to apply the experimental technique in the case of a new problem or a new variable.

Having said this, a few additional details will help to clarify these conclusions. Firstly, the instrument we used was applied to the analysis of laboratory manuals by 18 different individuals. Although these analysts were trained in the use of the instrument and performed their analyses very carefully, one cannot assume the instrument to be completely reliable. However, the differences in interpreting statements in order to classify them were small enough that we can have confidence in the quality of the results. For example, the differences related to predictions and hypotheses that could not easily be assigned with complete certainty to one or another of the categories. Secondly, we expected that the vague wording of some instructions in the laboratory manuals would complicate the analysis. This question was raised by Lunetta and Tamir,[9] citing the ambiguity of the following question from the *PSSC Physics Laboratory Manual*:

"Could you make a 'lens' that would focus rolling balls?"[10]

Fortunately, this sort of problem hardly ever arose. Generally speaking, the instructions for the laboratory operations are clearly drafted and easy to understand. Incidentally, subsequent editions of the *PSSC Laboratory Manual* have been revised and this question no longer appears. This suggests to us another reason for interpreting the conclusions cautiously. The multiple revisions that science textbooks undergo sometimes take the form of omitting certain experiments and/or adding new ones. Highly complex tasks may thus replace quite simple ones. However, the opposite may also occur. Finally, the various ways teachers select a specific number of experiments for the year from among those recommended by the authors will largely determine the nature, complexity and variety of the tasks that will be set for students. For certain textbooks, a different sampling from the one reported in Table VIII.3 might have produced a more or less favourable picture. The latitude given to teachers to choose from among a large number of experiments plays a role that should be examined more thoroughly.

We conclude, then, by raising some questions based on the information derived from the laboratory manuals. All ministries of education include in their guidelines (for all levels of schooling) aims concerning the development of scientific process skills. At the end of our analysis of these guidelines, we emphasized that all the scientific skills (observing, stating hypotheses, verifying experimentally, etc.) appear regularly at all levels. But most of the textbooks chiefly provide opportunities for developing only the more elementary skills. Should the wording of the guidelines be more modest, or should laboratory tasks be designed with a view to developing all the desired skills, including the high-level ones? In selecting textbooks, do teachers pay sufficient attention to the variety and adequacy of the tasks that students are expected to perform in the laboratory? In planning their instruction, are teachers taking this into consideration? Should authors of textbooks suggest such a large number of experiments to teachers without informing them of the consequences of the choices they must make?

Let us now consider the category of aims relating to the nature of science. Can a student, working in a narrowly circumscribed way, following "recipes" in the textbook, not sharing results and planning virtually nothing of an original nature, really be acquiring a concept of science consistent with that proposed in the guidelines?

Hugh Munby in his discussion paper, *What is Scientific Thinking?*, advocates teaching science for the sake of stimulating intellectual independence. If this is a desirable goal for science education, are the instructions in laboratory guides adequate?

These are all questions which arise from our data regarding laboratory manuals. In real life, however, acquiring a skill is more complicated than merely following instructions. Ultimately, the teacher must impart a fuller meaning to laboratory work. All the same, not all laboratory manuals help teachers develop the set of scientific skills called for in ministry guidelines.

In this study, we have avoided comparing individual textbooks and recommending one over another, for one important reason. We cannot claim, on the basis of the methodology we have used, that all the differences observed between different textbooks are truly significant. Our purpose was to identify trends to inform discussions about future directions in science education, and this has been done. To illustrate the difficulty of bringing out significant differences between various textbooks, Table VIII.4 compares selected data collected by Tamir, Lunetta *et al.* for three senior-years textbooks with our own findings. Two factors are obvious. Firstly, the particular sample of experiments selected can substantially affect the variety and level of the tasks demanded of students. Secondly, some of the differences may also be due to something other than the sampling; in particular, some analysts took account of instructions appearing in the teacher's book, whereas Tamir, Lunetta *et al.* confined themselves to instructions given to students.

Table VIII.4 – Structure and Task Analysis of Laboratory Work: Comparison with the Results of Tamir and Lunetta – Senior Years, Physics and Chemistry – percentages

Textbook Code		*PSSC**	*63*	*CHEMStudy O'Connor**	*54*	*CHEMStudy Parry**	*53*
Number of experiments analyzed		47	25	46	23	39	19
Structure							
a.3	Inductive approach	0	0	95.7	83	0.0	58
a.4	Deductive approach	0	100	28.3	17	12.8	47
Cooperative mode							
b.2	Students work on different tasks and pool results	2.1	0	2.2	0	5.1	21
b.3	Postlab discussion required	0.0	16	0.0	57	2.6	100
Task Categories							
1.0	*Planning and Design*						
1.1	Formulates a question or defines a problem to be investigated	0.0	0	0.0	0	0.0	0
1.2	Predicts experimental result	14.9	68	8.7	4	10.3	5
1.3	Formulates hypothesis to be tested in this investigation	0.0	4	0.0	4	0.0	0

Table VIII.4 – continued from previous page

Textbook Code	PSSC*	63	CHEMStudy O'Connor*	54	CHEMStudy Parry*	53
Number of experiments analyzed	47	25	46	23	39	19
1.4 Designs observation or measurement procedure	2.1	4	8.7	13	7.7	0
1.5 Designs experiment	2.1	0	8.7	4	5.1	0
2.0 Performance						
2.2 Manipulates apparatus; develops technique	97.9	92	95.7	70	97.4	68
2.3 Records result, describes observation	97.9	96	89.1	96	79.5	90
2.6 Works according to own design	0.0	0	15.2	9	2.6	0
3.0 Analysis and Interpretation						
3.1a Transforms result into standard form (other than graphs)	53.2	72	56.4	22	4.3	21
3.1b Graphs data	34.0	36	13.0	9	15.4	11
3.2a Determines qualitative relationship	93.6	36	71.7	44	84.6	42
3.2b Determines quantitative relationship	74.5	80	50.0	44	35.9	42
3.3 Determines accuracy of experimental data	23.4	12	11.4	4	20.5	26
3.4 Defines or discusses limitations or assumptions that underlie the experiment	4.3	24	2.2	17	17.9	5
3.5 Formulates or proposes a generalization or model	34.0	44	6.5	52	10.3	21
3.6 Explains a relationship	53.2	44	50.0	35	46.2	53
4.0 Application						
4.1 Predicts based upon the results of this investigation	23.4	40	15.2	44	28.2	37
4.2 Formulates hypothesis based upon the results of this investigation	23.4	4	6.5	9	12.8	26

**Source*: P. Tamir and V. Lunetta, "Inquiry Related Tasks in High School Laboratory Handbooks," *Science Education*, 1981, vol. 65, no. 5, pp. 477-484.

Table VIII.5a – Number and Types of Messages Inviting Students to Use their Knowledge of Science and Technology – Early Years (00); Middle Years, Biology (10), Physical Science (20), General Science (30)

Textbook code	01/03	02	04	11	12	13	14	15	16	17	21	22	23	24	31	32	33
Direct action																	
home	0	1	0	4	9	2	0	1	0	1	0	0	0	12	2	0	0
school	0	0	0	2	0	3	0	0	0	1	0	0	0	5	2	1	0
community	0	2	0	1	2	0	0	0	0	4	0	0	0	0	1	0	0
Gathering of information																	
home	0	1	0	0	0	0	0	0	0	1	0	0	1	2	0	0	4
school	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0
community	1	2	1	0	0	0	0	2	0	0	0	0	1	0	1	0	3
Reflection																	
home	0	0	0	2	0	0	0	1	0	0	0	0	8	16	0	0	6
school	0	1	0	1	0	22	0	0	0	1	0	0	1	6	2	0	1
community	2	5	0	1	0	0	0	0	2	1	0	0	1	6	2	0	1
Total	3	12	1	12	11	27	0	4	2	9	0	0	14	22	10	3	15

Table VIII.5b – Number and Types of Messages Inviting Students to Use their Knowledge of Science and Technology – Senior Years; Biology (40), Chemistry (50), Physics (60)

Textbook code	41	42	43	44	51	51a	51b	52	53	54	55	56	61	62	63	64
Direct action																
home	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
school	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
community	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Gathering of information																
home	3	0	0	6	0	0	0	0	0	0	0	0	0	2	0	0
school	0	0	0	6	0	0	1	0	0	0	0	0	2	0	0	0
community	0	0	0	4	0	0	0	0	0	0	2	3	0	0	0	0
Reflection																
home	18	1	0	2	0	0	1	0	0	0	0	0	22	1	0	0
school	0	0	0	0	0	0	0	1	0	0	5	5	0	0	0	0
community	0	0	0	0	0	0	0	8	0	0	0	2	0	0	0	0
Total	22	1	0	18	0	0	2	9	0	0	9	12	25	3	0	1

Science-Technology-Society Interaction

To determine if the resources provided by the authors of science textbooks enable students to reach aims relating to the social impact of science and technology, we collected the relevant messages and divided them into four categories (see Appendix D): the application of knowledge category, the socioeconomic category, the political category and the scientific responsibility category.

Application of Knowledge

These messages invite students to make use of their knowledge of science and technology in ways beneficial to themselves or their communities. Table VIII.5a-b indicates the number and distribution of these messages. The suggested activities are divided into three types: direct action, gathering of information and reflection; they are situated in three locations: school, home and community.

According to the information given in this table, the authors of science textbooks provide few or no activities involving the application of scientific or technological knowledge in society. When such activities are present in quantity (13, 24, 41, 61, for example), they are mainly reflective in nature. The total number of invitations to direct action (60) constitutes about one-fifth of the total number of activities, and these are addressed chiefly to middle-years students. In general, students are asked to conduct these activities at home and in the community rather than at school. The activities tend to be individual rather than collective (this latter trait is not indicated in the table). Note also that seven of the nine textbooks containing no messages about the application of knowledge do, nevertheless, contain an aim concerning the interaction between science, technology and society.

We have not attempted a systematic determination of the content of each message in this category. However, each analyst has picked out one or two examples of activities requested of the student. Out of 50 examples, 27 concern the environment or energy.

Table VIII.6a-b presents data concerning the messages in the other three categories. Messages in the socioeconomic category inform students of the beneficial or detrimental effects of science and technology on society at the national and international levels. The numbers and distribution of messages are accompanied by: the beneficial or detrimental character of the effects (according to the authors), whether or not there is a discussion and the context (national or international) in which the effect in question occurs. This latter information is also available for the other categories of messages. Messages belonging to the political category have a bearing on the ways in which a society exploits scientific and technological knowledge to solve national or international problems. The number of messages is accompanied by the number of solutions deemed certain and the number considered doubtful. Finally,

Table VIII.6a – Number of Science-Technology-Society Messages in Categories 2 (Socioeconomic), 3 (Political) and 4 (Responsibility) – Early Years (00); Middle Years, Biology (10) and Physical Science (20)

Textbook code	01	02	03	04	11	12	13	14	15	16	17	21	22	23	24
Socioeconomic Category															
Number of messages	5	18	9	5	8	2	13	4	15	9	5	2	0	2	13
Beneficial effects[a]	1	8	9	2	7	2	8	2	15	7	4	1	0	0	12
Detrimental effects	5	10	5	3	1	0	5	2	0	2	1	1	0	2	1
Discussion present	3	16	9	5	8	2	6	1	7	4	3	2	0	1	3
No discussion	2	2	0	0	0	0	7	3	6	5	2	0	0	1	10
National context	0	1	0	0	1	0	0	1[c]	1	2	4	1	0	0	4
International context[b]	3	17	9	5	8	2	13	3	14	8	1	1	0	2	9
Political Category															
Number of messages	0	5	6	4	5	0	6	4	17	2	1	3	0	2	1
Solution certain	0	4	5	4	2	0	4	4	12	2	0	3	0	2	1
Solution doubtful	0	1	3	0	3	0	1	0	5	0	1	0	0	0	0
National context	0	0	0	0	3	0	0	1	1	1	0	1	0	0	1
International context[b]	0	5	6	4	3	0	6	3	16	1	1	2	0	2	1
Responsibility Category															
Number of messages	1	10	1	1	3	1	6	0	1	0	1	0	0	1	1
Ethical type	1	5	1	1	3	1	2	0	0	0	1	0	0	1	0
Legal type	0	5	0	0	0	0	4	0	1	0	0	0	0	1	1
National context	0	0	0	0	3	0	1	0	0	0	0	0	0	1	1
International context[b]	1	10	1	1	0	1	5	0	1	0	1	0	0	0	0
Total number of messages	6	33	16	10	16	3	25	8	33	11	7	5	0	5	15

[a] An effect may be considered simultaneously beneficial and detrimental. It is then counted in both categories.
[b] The context may occasionally show both characteristics and is then counted twice.
[c] Africa.

Table VIII.6b – Number of Science-Technology-Society Messages in Categories 2 (Socioeconomic), 3 (Political) and 4 (Responsibility) – Middle Years, General Science (30); Senior Years, Biology (40), Chemistry (50), Physics (60)

Textbook code	31	32	33	41	42	43	44	51	52	53	54	55	56	61	62	63	64
Socioeconomic Category																	
Number of messages	8	4	11	23	17	3	1	3	10	4	2	27	6	5	2	0	0
Beneficial effects[a]	8	4	3	11	16	0	0	2	3	0	0	1	1	1	1	0	0
Detrimental effects	1	0	7	12	6	3	1	1	7	4	2	26	5	4	1	0	0
Discussion present	8	1	5	17	15	0	0	0	10	1	2	21	1	4	1	0	0
No discussion	0	3	5	6	2	3	1	3	0	3	0	6	5	1	1	0	0
National context	2	1	10	12	9	3[c]	1	2	0	1[c]	0	3	1[c]	1	1	0	0
International context[b]	8	3	1	10	8	0	0	2	10	3	2	24	5	4	1	0	0
Political Category																	
Number of messages	1	3	11	8	6	2	1	0	3	8	3	8	4	9	4	0	0
Solution certain	1	3	7	8	3	1	1	0	2	5	0	6	4	9	3	0	0
Solution doubtful	0	0	4	0	3	1	0	0	1	4	3	2	0	0	1	0	0
National context	1	0	9	4	0	1[c]	1	0	1	1[c]	0	0	0	1	0	0	0
International context[b]	0	3	2	4	6	1	1	0	2	7	3	8	4	8	4	0	0
Responsibility Category																	
Number of messages	1	0	4	8	6	0	1	0	2	2	0	11	0	2	1	0	0
Ethical type	1	0	3	8	6	0	0	0	2	2	0	6	0	1	1	0	0
Legal type	0	0	1	0	0	0	1	0	0	0	0	5	0	1	0	0	0
National context	1	0	4	4	2	0	1	0	1	0	0	2	0	1	0	0	0
International context[b]	1	0	0	4	5	0	0	0	1	2	0	9	0	1	1	0	0
Total number of messages	10	7	26	39	29	5	3	3	15	14	5	46	10	16	7	0	0

[a] An effect may be considered simultaneously beneficial and detrimental. It is then counted in both categories.
[b] The context may occasionally show both characteristics and is then counted twice.
[c] United States.

messages in the category of scientific responsibility deal with the moral and legal aspects of scientific and technological activity.

The socioeconomic category contains the most messages (55 per cent of the total), the political category follows (30 per cent) and the scientific responsibility category (15 per cent) contains the fewest. With few exceptions, this pattern is true for every textbook. Three of the 32 textbooks in the sample contain none of these messages and seven contain five or fewer. For the set of textbooks as a whole, the number of beneficial effects of science and technology recorded is equal to the number of detrimental ones. In this respect, we can distinguish three kinds of textbooks: those that are optimistic and for which the impact of science and technology is seen as more often beneficial than detrimental (eight out of 32), those that are pessimistic and for which the perceived impact is more detrimental than beneficial (seven of 32) and those that present an equal number of beneficial and detrimental effects. In two-thirds of the cases, the beneficial or detrimental character of the effects is the subject of discussion and very few textbooks present effects without any discussion. When science and technology are called upon to solve societal problems, the solutions are seen as certain two times out of three and uncertain only once in three times. When the authors do introduce material about scientific responsibility, they are more apt to illustrate the moral rather than the legal aspect. They do either, however, only rarely. Finally, the messages are presented generally in an international or, at any rate, not specifically Canadian context. On some occasions, the context is clearly both Canadian and American.

Counting the number of messages, however, provides only partial information. Possibly a small number of very pertinent messages (relating to the official guidelines) are more effective than a great many messages of lesser interest. Our purpose at this point is not to discuss the relevance or quality of the messages, even though we recognize that such a discussion is essential.

Socioeconomic Category

Some 230 messages of this category, taken from the 32 textbooks and two supplementary booklets, in which the good or bad consequences of science and technology for society were expressed, were divided into five major groups of varying size. One message is given to represent each group and is accompanied by the number of messages contained in that group.

Group A: "Growth or progress resulting from science and technology creates pollution, causes illness and disturbs the ecosystem." This group contains 98 messages, slightly fewer than half the total number of socioeconomic messages. It includes nearly everything that has made headlines during the last 15 years: water, air and soil pollution; heavy-metal poisoning; the problems due to the use of DDT and chemical fertilizers; and the destruction of the environment as a result of mining activity, the construction of dams, intensive agriculture and urbanization.

Group B: "Science and technology have created medicines and techniques for improving public health and combatting malnutrition." This group, the second in size, contains 55 messages that appear primarily in biology textbooks. The consequences they describe are broadly beneficial: from pasteurization to the application of x-rays, from synthesizing new foods to genetic engineering.

Group C: "Science and technology have created machines or processes to facilitate work or increase the wellbeing of the population." This group contains 27 messages, just over 10 per cent of the total number. They point to the improvement of living conditions made possible by electricity, anti-pollution devices and improved transportation methods. The beneficial effect of space exploration gets a single mention, as does the introduction of data processing. Only two messages deal with the benefits brought by telecommunications.

Group D: "Science and technology have made possible the creation of beneficial new materials and new sources of energy." In this group 23 messages mention cheaper, more readily available synthetic materials to meet people's needs. Students also learn about the usefulness of nuclear and solar energy.

Group E: "Growth or progress resulting from science and technology entails the squandering of energy and resources and gives rise to problems of waste management." This group contains 20 messages.

Group F: This last group contains seven messages, summarized as follows: "science and technology, by their effects on society, are inducing people to conserve resources and energy, and to take action against pollution."

We shall confine ourselves here to a few comments on the results of this analysis. At first glance, according to textbook authors, pollution and the waste of resources are the most important consequences of science and technology. This conforms fairly well with the temper of the times during the 1970s. According to our sample, the benefits of science and technology appear to come almost exclusively from medical research. Finally, the effects of data processing and telecommunications, phenomena that are likely to change the society of the 1980s, are conspicuous by their absence in the physics, general science and physical science textbooks we have examined.

What is the message implied in this distribution of the social consequences of scientific and technological activity? What are its likely effects on the development of attitudes towards science and technology?

Political Category
What kinds of social problems can science and technology be called upon to solve? Our analysis discerned about 40, scattered throughout the 34 books examined. World hunger and diseases (about 30 messages) and, oddly enough, those created by science and technology such as pollution and the need for new sources of energy (about 30 messages) are mentioned most often. The others to which science and technology can offer solutions are quite diverse: for example, weather prediction, prevention of natural disasters by the construction of models, purification of drinking water. Each of these is mentioned only once in our sample.

Scientific Responsibility
The moral problems associated with science and technology and focussed upon in science textbooks are: personal attitudes to pollution and waste (about 10 messages, one-fifth of the total); questions concerning life in society (such as the use of drugs), genetic engineering and genetic counselling (about seven messages); a variety of other problems, each mentioned only once, such as the decision to undertake mining operations, deforestation and whaling. The legal problems associated with scientific and technological activity that are mentioned are again those concerning pollution and waste (about two-thirds of the 20 messages).

Before concluding, we must again utter a word of caution. Firstly, the textbooks containing most messages relating to the interaction of science, technology and society do not necessarily offer the greatest variety of messages. Textbook 55, for example, which contains 46 messages, the largest number of all the textbooks, concentrates almost all of them in the last chapter (5 per cent of the book's pages) entitled "Chemistry, environment and pollution." Likewise, textbook 41's 39 messages are found in the last chapter, "Humans in the Web of Life" (6 per cent of the book's pages). Does this mean that it is essential to know everything that precedes this material in the textbook before being introduced to the social effects of science and technology, or does it mean, rather, that the place given these effects in the book reflects the priorities of the authors? Interestingly, other textbooks follow an opposite course. For example, textbook 31 starts out as follows:

> "In recent years you have probably heard a great deal about energy. You may have read about rising fuel prices and further shortages of energy. You have been warned about an energy crisis and told to conserve energy."[11]

In this textbook the chapter containing most messages relating to the interaction between science, technology and society, "How Our Use of Energy Affects Our World," is the tenth of 29 chapters, about 5 per cent of the book. However, the trend towards introducing a social perspective into science textbooks is fairly recent and, as we have just seen, this process is being carried out in a variety of ways depending on the importance given to it by authors.

Secondly, the number of messages does not truly reflect the importance given by science textbook authors to the interaction between science, technology and society. Very few of the messages are long or documented as well as one might wish. In fact, most of them are short, call for discussion or require additional information. About 200 messages out of 230 occupy from one to 10 per cent of a chapter. Only textbooks 31 and 42 offer messages occupying from 20 to 100 per cent of a chapter. Two of these messages, the longest ones, deal with the rational utilization of energy and the effects of science and technology on human ecology.

Furthermore, this says little directly about educational practice. Indeed, even if teachers do use textbooks for preparing their lessons, they may be inspired by certain parts of them to introduce a social perspective. However, our survey shows that the introduction of this perspective is not a priority for the majority of teachers.

We have presented a somewhat sketchy picture of the interaction of science, technology and society in science textbooks. We have described the aspects of this interaction that are most often mentioned in the textbooks and have shown the spread that exists between textbooks in this regard. Generally speaking, on the basis of the number of messages, general science textbooks and biology textbooks show more social context than textbooks of the physical sciences. Some textbooks provide no opportunities for students to reach goals in this area; others provide very few. Given the prevailing ministry guidelines, it is extremely difficult to determine how much social context and of what kind is sufficient to realize these aims.

The Canadian Context

Table VIII.7a-c indicates the number, type and length of messages that make up the Canadian context in the science textbooks examined. The analytical scheme (reproduced in Appendix D) was intended to enable us to determine the extent to which a Canadian context is present, this being defined as the total number of messages in a textbook that are unequivocally linked to the Canadian reality in all its aspects. The scheme was also intended to enable us to count the situations in which the Canadian context is unnecessarily replaced by a foreign one.

The messages were assigned to four categories: physical (geographic), historical, sociocultural and foreign. In Table VIII.7a-c, the number of messages is accompanied by the number of supportive photographs, illustrations or diagrams and by the (approximate) number of lines of text devoted to these messages. Each part of the table contains notes intended to give details about the data presented.

Table VIII.7a – Number, Type and Length of Messages Relating to the Canadian Context in Science Textbooks – Early Years (00); Middle Years, Physical Science (20), General Science (30)

Textbook code	01	02	03	04	21	22	23	24	31	32	33
Physical Dimension											
Total number of messages	7	6	2	7	4	0	2	6	100[c]	12	15
Photographs, illustrations, etc.	5	4	1	5	3	0	1	1	10[b]	5	3
Total number of lines	16	7	7	16	23[e]	0	17	100[d]	600[d]	60[d]	40[d]
Historical Dimension											
Total number of messages	0	0	0	0	0	0	0	0	5	0	3
Photographs, illustrations, etc.	0	0	0	0	0	0	0	0	2	0	2
Total number of lines	0	0	0	0	0	0	0	0	15[d]	0	25[d]
Sociocultural Dimension											
Total number of messages	0	0	7	0	0	0	2	2	30[c]	1	10
Photographs, illustrations, etc.	0	0	0	0	0	0	1	0	3	0	5
Total number of lines	0	0	35	0	0	0	4	40[d]	180[d]	3	70[d]
Foreign Context											
Total number of messages	6	0	0	0	2	0	4[g]	0	1	4	2
Photographs, illustrations, etc.	4[a]	0	0	0	2[f]	0	0	0	0	2	1
Total number of lines	10[b]	0	0	0[b]	2	0	80[d]	0	2	50[d]	1

[a] Photographs of geological formations mostly taken in the United States.

[b] Apparently the illustrations vary with the editions. On page 279 of the *STEM* text, 5th year (1977 ed.) and on the same page of its translation, *Les chemins de la science*, 5th year (1978 ed.), a set of photographs taken on the earth and on the moon are shown for the children to think about. The English edition retains the American flag, while the French edition replaces it with a Canadian flag.

[c] Minimum.

[d] Approximate.

[e] Discussion of the adaptation of S.I. system to Canada.

[f] Photograph of a nuclear power station in the United States.

[g] Regular reference to North America rather than Canada.

Table VIII.7b – Number, Type and Length of Messages Relating to the Canadian Context in Science Textbooks – Middle and Senior Years, Biology (10 & 40)

Textbook code	11	12	13	14	15	16	17	41	42	43	44
Physical Dimension											
Total number of messages	29	2	51	3	15	12	0	8	3	1	35
Photographs, illustrations, etc.	20[a]	1	14	2	4	34	0	5	3	0	14
Total number of lines	800[a]	3	120[b]	4	26	70[b]	0	20[b]	35[b]	23	800[b]
Historical Dimension											
Total number of messages	1[c]	0	0	0	2	0	1	0	1[h]	0	14
Photographs, illustrations, etc.	0	0	0	0	2	0	0	0	0	0	6
Total number of lines	4	0	0	0	18	0	2	0	29	0	400[b]
Sociocultural Dimension											
Total number of messages	3	0	3	0	5	3	0	0	2	0	14
Photographs, illustrations, etc.	0	0	1	1	1	0	0	0	0	0	2
Total number of lines	14	0	7	0	30[b]	20[b]	0	0	18	0	300[b]
Foreign Context											
Total number of messages	8	0	2[e]	10[f]	0	10	2	17[g]	8	14[g]	1
Photographs, illustrations, etc.	1	([d])	0	2	0	7	1	7	2	4	0
Total number of lines	40[b]	0	20[b]	15[b]	0	50[b]	30[b]	100[b]	50[b]	300[b]	40[b]

[a] Minimum.
[b] Approximate.
[c] The potato famine led to the Irish immigration to Canada in 1885.
[d] All the photographs in this human biology textbook were taken in France.
[e] Canada overlooked as a world producer of wheat.
[f] All the examples come from the United States.
[g] Examples taken from the United States.
[h] Development of the McIntosh apple in Canada.

Table VIII.7c – Number, Type and Length of Messages Relating to the Canadian Context in Science Textbooks – Senior Years, Chemistry (50), Physics (60)

Textbook code	51	51a	51b	52	53	54	55	56	61	62	63	64
Physical Dimension												
Total number of messages	8	9	6	3	0	0	13	1	21	22	0	0
Photographs, illustrations, etc.	2	3	5	2	0	0	10	0	16	9	0	0
Total number of lines	70[b]	160[b]	2	70[b,c]	0	0	15	2	60[b]	120[b]	0	0
Historical Dimension												
Total number of messages	0	2	0	3	3[d]	1[d]	2	0	5	1[f]	0	0
Photographs, illustrations, etc.	0	0	0	1	0	0	0	0	7	0	0	0
Total number of lines	0	25	0	90[b]	15	30	13	0	110[b]	6	0	0
Sociocultural Dimension												
Total number of messages	0	3	1	2	0	0	4	2	40	10	0	0
Photographs, illustrations, etc.	0	0	0	0	0	0	0	0	9	0	0	0
Total number of lines	0	16	2	40[c]	0	0	40[b]	2	300[b]	70[b]	0	0
Foreign Context												
Total number of messages	0	0	1	0	11	10[e]	1	4	4	7	0	0
Photographs, illustrations, etc.	0	0	1	0	1	3	0	4	2	4	0	0
Total number of lines	0	0	0	0	100[b]	50[b]	1	5	20[b]	30[b]	0	0

[a] Minimum.
[b] Approximate.
[c] Mainly Atomic Energy of Canada Ltd.
[d] The scientists mentioned are Gillespie and/or Bartlett.
[e] All the examples are from the United States.
[f] Rutherford.

The absence of Canadian context in science textbooks used in Canada was noted in the Symons Report[12] and was the subject of a discussion paper written by James Page.[13] As the analysis of the guidelines in chapter 5 indicated, the presence of such a context is not, with rare exceptions, the subject of special mention in the science curricula. Moreover, as the responses to the survey show (see volume II), the teachers assign practically no importance to the acquisition of an awareness of the practice of science in Canada as an aim of science instruction. The presence of a Canadian context in science textbooks is clearly a matter for deliberation.

The textbooks examined fall into two main categories (see Table VIII.7). The first comprises textbooks devoid of Canadian context – those that, at worst, contain not a single message relating to the Canadian reality and, at best, only a few meagre geographical, historical or sociocultural references. All four textbooks at the early-years level (01, 02, 03 and 04), the middle-years biology texts (12, 14 and 17), physical science books of the middle years (21, 22 and 23), chemistry textbooks of the senior years (53, 54 and 56) and biology and physics textbooks of the senior years (41, 42, 43, 63 and 64) fall into this group. These textbooks make up about 60 per cent of the sample examined. This category can be divided into two subcategories. The first contains the textbooks that have very little or no Canadian or foreign context (01, 02, 03, 04, 12, 17, 21, 22, 23, 56, 63 and 64). In some, a few indications here or there betray their foreign origin and their adaptation to the Canadian market (for example, flags and other illustrations). The second subcategory shows a foreign context (in most cases a US context), where Canadian examples would also have been appropriate. Here are a few examples of this subcategory cited by the analysts.

Textbook 14:

> "The metric system came into use in France in 1840. By 1878 its use had spread to Belgium, Greece, Spain, Germany, and Sweden. The metric system has been legal in the United States since 1866."[14]
>
> "Most people in the United States live in cities."[15]

Textbook 41: Students learn here the course of the mortality rate in the United States during the twentieth century, the emigration and immigration rates in the United States from 1911 to 1940 and the population densities of Rhode Island and Maine, but nothing of a comparable nature about their own country.[16] The same textbook proposes a professor at the University of California at Berkeley[17] as a career model, but nowhere does it refer to a Canadian scientist or university.

Textbook 42: Here again the population statistics are given for the United States and the acid rain phenomenon does not seem to apply to Canada.[18]

Textbook 43: The student learns the maximum quantities of alcohol that US drivers may imbibe before driving.[19] The percentage of racial types are given for the United States (blacks and whites), Sweden, Japan, Hawaii, China, the aborigines of Australia and the native people in North America, but not for Canadians.[20]

Textbook 53:

> "Imagine that a telegram is to be sent on a winter night from New York City to a rancher who lives near the top of a mountain in Nevada."[21]
>
> "Over 20 million lbs. of aspirin, or about 155 5-grain tablets for every person, are manufactured each year in the United States alone."[22]

Textbook 54:

> "A dam such as the Hoover Dam on the Colorado River stores water. It also can be said to store energy. Explain."[23]

It is noteworthy that the French version of this textbook contains the following exercise:

> "A dam such as the Manic 5 Dam on the Manicouagan River stores water. It also can be said to store energy. Explain."[24]

Examination of the French versions of American textbooks showed that, in the majority of cases, translation had been accompanied by adaptation to take account more effectively of the Canadian reality and to eliminate obviously foreign references. In its French version, textbook 54 would be more appropriately included in the first subcategory: little Canadian or foreign context. We take this opportunity to emphasize the difficulty of assigning a textbook clearly to one category or another in the absence of definite criteria for determining Canadian context. Do such criteria exist? If not, should some such criteria be established?

The second category of textbooks (11, 13, 15, 16, 24, 31, 32, 33, 44, 51, 52, 55, 61 and 62) contains a certain amount of Canadian context. This may vary from one textbook to another and may be of varying importance, but it is there and students may learn a little, at least, about their own country. On the whole, these textbooks give many physical and geographical references. Some are frankly regional in tone and thus offer much information about British Columbia (31), Alberta (51 and supplements), Ontario (44) and Québec (almost all the French-language textbooks are written or adapted for this province). The sociocultural dimension is given less prominence than the physical, but more than the historical, which is the most neglected of the three. The collection of messages constituting the Canadian context is very varied and difficult to summarize. We shall try to illustrate this variety by giving a few examples of the historical and sociocultural dimensions.

As stated above, the history of science and technology in Canada is almost completely ignored by science textbooks. Rutherford's experiments at McGill University (1889-1907) are often cited as an example of Canadian science (textbooks 61 and 62). Neil Bartlett is mentioned in three textbooks (31, 53 and 54) for his synthesis of Xenon hexafluoride at the University of British Columbia and R.J. Gillespie of McMaster University is mentioned in one textbook (53) for his theory of molecular structure. In another field, Sir Sandford Fleming is honoured for his proposal to establish time zones and his role in the construction of the first trans-Canadian railroad (31). Sir Frederick Banting is mentioned once for the isolation of insulin (52). The historical role of Atomic Energy of Canada is more or less recognized in three instances (52, 61 and 62). One booklet in the *ALCHEM* program (51a) mentions the history of the petrochemical industry in Canada, and of polyethylene in Alberta. Textbook 44 contains the most historical content. References abound in it: for example, the role of Alexis St-Martin in the study of digestion, the study of heliotropism by Kevan of the University of Newfoundland, the study of the Dionne quintuplets. However, this biology textbook, like all the others, ignores the basic role of Brother Marie-Victorin both as the scientific editor of "La flore Laurentienne" (Laurentian Flora) and as a promoter of science in French Canada.

Sociocultural messages predictably relate largely to matters of pollution and the management of energy as these affect Canada (15, 23, 24, 33, 44, 52, 55, 61 and 62). Only one textbook (33) deals with mining as an important factor in Canadian life. In others (11, 15), it is rarely mentioned. The northern character of Canada in relation to science and technology is mentioned only very occasionally: the cold climate (31, 44), the forests (03, 15, 16, 44), the water (32) and the fauna (13, 16, 44). Only one textbook (31) deals with the Canadian lifestyle, especially the diet and its deleterious effects in the light of medical and dietary discoveries and the exhortatory and regulatory role of governments. Finally, some 10 textbooks in our sample touch on students' career plans and only eight of these offer the student detailed information about careers in science and technology. Of the eight, seven were written in the United States and they are the ones that give most career information.

In conclusion, we can say that Thomas H.B. Symons and James Page were right. Generally speaking, the science textbooks in use in Canadian schools teach almost nothing about science and technology in Canada, or about its history and impact on society. Teachers who wish to inform their students on these matters must look for relevant sources of information elsewhere.

Table VIII.8 – Characteristics of Science Textbooks Containing a Canadian Context – Early Years (00); Middle Years, Biology (10), Physical Sciences (20), General Science (30); Senior Years, Biology (40), Chemistry (50), Physics (60)

Textbook code	11	13	15	16	24[a]	31	32	33[b]	44	51	52	55[c]	61	62
Authors														
Number	5	2	2	2	2	2	2	6	2	10	2	3	3	4
Canadians	5	1	2	2	2	2	2	6	2	10	2	3	3	4
Americans														
Others														
Not identified		1												
Publishers														
Canadian[d]		X		X	X			X		X				X
Subsidiary[e]	X		X			X	X		X		X	X	X	
Foreign														
Printed in														
Canada	X	X	X	X	X	X	X	X	X	X	X	X	X	X
United States														
Other														
Not determined														

[a] Textbook no. 24 is a French translation of a Canadian textbook published by a subsidiary and printed in Canada.

[b] Textbook no. 33 has been translated into French.

[c] Textbook no. 55 has been translated into English and is the first science textbook written by Québec authors to have been so translated into English.

[d] Canadian ownership. Of the six publishing houses in this line, three are Québec publishers (13, 16, 24), two are Ontarian (33, 62), and one is Albertan (51).

[e] Canadian subsidiary of a multinational publishing company.

Table VIII.9 – Characteristics of Science Textbooks Containing Little or No Canadian Context – Early Years (00); Middle Years, Biology (10), Physical Sciences (20), General Science (30); Senior Years, Biology (40), Chemistry (50), Physics (60)

Textbook code	01[a]	02[a]	03	04[b]	12	14	17	21	22[a]	23[b]	41	42	43[b]	53	54[b]	56[b]	63[b]	64
Authors																		
Number	4	8	5	4	3	2	4	3	5	3	([g])	1	3	4	5	2	3	6
Canadians			2[e]		1					3								6
Americans	4	8	3	4		2	4	3	5		([g])	1	2	4	5	2	3	
Others				2[f]														
Not identified													1					
Publishers																		
Canadian[c]	X	X			X				X									X
Subsidiary[d]			X	X		X	X	X		X		X	X	X	X	X	X	
Foreign											X							
Printed in																		
Canada	X	X					X			X								X
United States				X		X					X		X	X	X	X	X	
Not identified			X		X			X				X						

[a] Textbooks nos. 01, 02 and 22 are French translations of American texts.
[b] There are French translations of texts nos. 04, 23, 43, 54, 56 and 63 in use in the Francophone schools of Canada.
[c] Canadian ownership; the 5 entries in this line are Québec publishing houses.
[d] Canadian subsidiary of a multinational publishing company.
[e] British Columbia.
[f] France.
[g] The 1978 edition of this textbook lists more than 50 collaborators, all of them Americans.

However, a very few textbooks do succeed in providing both teacher and student with a science content in a Canadian context. What are the characteristics of the authors and editors of these texts? Table VIII.8 clearly shows that when a Canadian context is present the textbook has been written by Canadians. On the other hand, the fact that the authors are Canadian does not necessarily predict the presence of a Canadian context (see Table VIII.9). The authors of 14 out of the 18 textbooks that have little or no Canadian context are American; and the existence of a US context in several of the textbooks shows that no effort has been made to adapt them to the Canadian reality. This is confirmed by the fact that seven of these textbooks were written and printed in the United States. In this category, English-language publishers are not represented, unlike their Québec counterparts, who publish French translations of American works. Tables VIII.8 and VIII.9 also show that the textbooks that offer the least information on science and technology in Canada and on its history and social impact are used primarily in the early and senior years. To supplement the data and to assess the relative importance of textbooks with and without Canadian context, Table VIII.10 indicates the extent of their utilization by the respondents to our survey.

Table VIII.10 – Number of Survey Respondents Using Textbook With and Without a Canadian Context

	Textbooks with Canadian Context	Textbooks without Canadian Context	Others (with or without context)
Early Years	0	705	94
Middle Years	332	168	307
Senior Years			
Biology	7	154	110
Chemistry	60	64	143
Physics	82	53	65

The Nature of Science; the History of Science and Technology

This textbook analysis contains a section on the nature of science for two reasons. Firstly, official guidelines contain objectives relating to the nature of science, such as: "to understand how science operates." Secondly, the views of critics of science education justified such an inclusion. For example, Jacques Désautels stated in his book, *École + Science = Échec* (School + Science = Failure):

> "A first analysis of the popular view of science and engineering and their relationship to the development of scientific knowledge, shows that an inaccurate view of reality is being conveyed, one that

keeps myths alive. Teaching based on this view serves to alienate the student."[25]

We are immediately faced, then, with a number of questions. The first stems from the very nature of the study and asks what opportunities textbook authors give students to understand the nature of science. The second asks how the history of science is introduced and used by authors to illustrate the nature of science. These questions seem rather technical, but we soon realized that concepts such as the history of science and the nature of science have different meanings for different authors, and that messages about these concepts are often unstated. Again, our study is not a normative one, and for this reason, we could not very well start from one generally accepted definition of the nature of science (if, in fact, one existed) and compare it with those given, implicitly or explicitly, by authors. Rather, this study presents a descriptive analysis of a multifaceted and complex reality that can be called simply "textbook science." But what exactly is textbook science? This question is difficult to answer, especially since there has been very little research on the subject. Moreover, the image of science that a textbook portrays is only one of many the student has access to. In fact, any image of the nature of science that a student has is likely to be developed from a blending of his own preconceptions with "spontaneous philosophies" of science held by his teacher and by textbook authors. It is therefore difficult to infer anything about a student's concept of science from messages contained in textbooks.

At first glance, "textbook science" appears to operate on two levels. At the level of rhetoric, this is apparent from the definitions that the authors give. At the level of practice, it can be discerned by examining the type of activities required of the student (if, in fact, the authors want students to work like "real" scientists), by reading the textbooks' messages that suggest to the student that "science operates this way" and by determining why and how authors refer to the history of science. These historical references generally give the student, either implicitly or explicitly, an idea of the nature of science. Even for one textbook, this is a considerable task. We have restricted ourselves to a cursory overview for the purposes of this analysis, and more work needs to be done. Though limited in number, our data nevertheless enabled us to raise several questions for deliberation.

Questions About the Nature of Science Activity

Messages about the nature of science often appear in the form of definitions of science and the scientific method. Almost all textbooks contain some information of this sort. This is especially true of early-years textbooks which, although not including anything for students' use, provide teachers with messages such as the following:

"The program is designed to help children become skilled at applying other processes such as: observing, measuring, recording, interpreting data, using numbers, predicting, classifying, communicating, formulating hypotheses."[26]

This is also the case, occasionally, with textbooks used in later years, whose authors view science as a collection of facts, discoveries and so on, to be "transmitted" to students:

"As was the case with the cell, the authors wish to point out, in these as in all the other chapters, the latest discoveries in science and to have students read about them in accounts that are clear and straightforward."[27]

The vast majority of textbook authors tell the student that science represents both a product and a process, even though this is expressed in various ways. Most give a definition of science (or of their own subdiscipline — biology, chemistry, physics, etc.) followed by a definition of scientific method as a means to resolve problems and add to the general body of scientific knowledge.

Our analysis has shown that authors of six of the 14 textbooks used in the middle years and seven of the 14 books used in the senior years give a schematic description of the scientific method that includes the following steps (though not necessarily in the same order): definition of problem, observation, gathering of information, formulation of hypothesis, designing of experiment with controlled variables, verification, and communication of results. This method appears in all three subjects (physics, chemistry and biology). Some middle-years textbooks (17, 31 and 33) do not contain such a description but instead emphasize the control of variables to ensure successful experimentation. Here, the significant question is not "how do you explain a phenomenon?" but rather, "what does such a phenomenon depend on?" In the senior years, only one chemistry textbook fails to give a schematic definition of science (51). The textbooks do, however, contain implicit messages. On the whole, physics textbooks stress observation and experimentation as the driving elements of scientific activity, with model and theory construction the expected outcome. Only one biology textbook (43) includes not only a traditional description of scientific method but also one for "technological method," which involves following a procedure to the letter, observing carefully and transcribing all data.

Several of the authors who do list the steps involved in the scientific method, nevertheless, do so with reservations:

"In practice, a scientist might not use all the steps listed. Studies of the work of successful scientists show that problem solving is not a step-by-step process. Scientists are creative people. They solve problems in many ways. Creativity, luck, hard work, and intelligent guessing are all part of scientific problem solving."[28]

"The traditional form of the scientific method is first observing nature, then seeking the regularities in the observations (etc.). This is

> a good method and it may be acceptable to some scientists. However, any method which is a combination of curiosity and imagination and which uses experimentation to look for regularities in nature will be an acceptable method for scientists to use."[29]

In any case, we have to ask ourselves why such a description of the scientific method (often followed by laboratory or historical examples) appears so frequently in science textbooks. It certainly does provide information; according to the authors, this is the way scientists work and this is the method to be described. To this, authors bring several implicit scientific and pedagogical assumptions: not only do scientists work this way, but this is the way students *should* work:

> "Your study of physics will in some ways imitate the steps by which more accurate knowledge of the world has been gradually won."[30]

One author maintains that, once the steps involved in the scientific method are mastered from the beginning, then the rest will follow more easily:

> "Once [these processes] have been mastered by the students, they are used in all subsequent units to introduce and develop the content of science."[31]

Defining science as both a product and a process, therefore, has two aims: it shows the student how to work; and it shows that scientists do, in fact, work this way themselves. However, we have already seen, from analyzing laboratory exercises, that very seldom is the entire range of skills involved in the scientific method ever brought into play. In addition, we ask: to what extent do textbooks demonstrate that science does, in reality, conform to the procedural description given in the initial chapters? On the whole, authors make some effort to prove this claim, though never compromising on the amount of content that they must cover for a school year. This explains why theoretical entities are introduced in textbooks as if their discovery were self-evident:

> "Then in 1932 the *neutron* was discovered. This is a particle with a mass almost the same as that of the proton (actually it is just slightly heavier), but it has no electrical charge."[32]

When one reads science textbooks from an epistemological perspective, one gains the uncomfortable feeling that perhaps they were not written with the intention of shedding light on the nature of science at all. Instead, this notion appeared fairly recently when the concept of "science as process" became a dominant theme in science education. Or, indeed, is the science course the place to teach about the nature of scientific activity? As has been shown by Orpwood and Roberts,[33] and in greater detail by Factor and Kooser,[34] this can occur, almost involuntarily, without either the student or the teacher being aware of the model being suggested. To make explicit what is implicit about the nature of science would remedy only part of the problem. The question remains: what view of science should be taught? Scientific activity, as described in most of the textbooks we examined, is essentially inductive in nature. However, the way in which content and laboratory sessions are organized does not favour this approach (see analysis of laboratory exercises). One can ask, as do Factor and Kooser, if this habit of describing explicitly the nature of science does not represent an element of what they call the "standardization" of textbooks.[35]

Apart from this inductivism, other characteristics that authors attribute to the nature of science include cooperation and communication:

> "The fourth activity of science is, in many ways, the most important one of all. It is only through communicating ideas to others that a strong framework can be provided for science. Experimental results must be confirmed and explanations must be tested by others."[36]

From examining science textbooks, it is obvious that, on the one hand, the only act of communication asked of the student is for a laboratory report to be handed in. Usually, this entails no cooperation with classmates and at no time does the student have any original publication to look at or discuss as evidence of scientific communication. Moreover, only one textbook, *ALCHEM 10* (51), gave a different account of scientific communication than that mentioned earlier. It implicitly states: a) scientists share information in order to advance theoretical development; b) several scientists working independently may discover the same thing; and c) scientists taking part in a competition may withhold information for personal or national reasons.

The final characteristic of the nature of science that we considered was its essentially dynamic quality: the products of science continually change.

> "Over the centuries, man has very often altered his views about the structure of matter. Theories are not necessarily truths, but instead are only temporary explanations."[37]

Generally, science has been successful in rectifying inaccurate representations. However, the ideas that a student has prior to science courses ("prescientific representations"[38]) are completely ignored. A textbook will state, for example, that "the novice has no prior basis for believing that the atom is planetary,"[39] when, in fact, children are widely exposed to this model in popular science programs, comic strips, advertising slogans and so forth.

The questions raised by the preceding remarks focus on the priority that should be given to knowledge about the nature of science and on ways to acquire it. In any case, it is very difficult to escape the need to determine the true nature of science. As Factor and Kooser state:

> "If science is indeed part of the search for truth and if truth seeking is its paramount internal value (as many writers say it is), then is there not a more truthful account of the nature of science itself?"[40]

In the meantime, it may be worthwhile examining in greater depth the suppositions implicit in textbook authors accounts of how scientific knowledge is developed, even though this is a difficult task and few researchers have ventured into this area.[41]

Questions About the History of Science and Technology

The use of history of science in textbooks is particularly interesting, for although history objectives appear to have no particular importance for either ministries of education or teachers, very few textbook authors (except at the early years) choose to disregard the history of science completely. Historical messages range between two extremes: the first consists only of the names of scientists and the dates of their discoveries; the second features detailed case studies from the history of science. On the whole, authors rarely state objectives concerning the history of science and, when they do, they are not always set out in a clear and straightforward manner.

> "Students should recognize the contributions made by various people to scientific knowledge."[42]
>
> "To provide some historical perspective for the development of the science."[43]
>
> "To show you some of the great ideas of science that have changed the world in the past and will again in the future."[44]
>
> "Understanding the historical development of biological concepts and their dependence on the nature of society and technology of each age."[45]
>
> ". . . so students can better understand the significance of the recent discoveries in biology if they first learn the classical statements of the problem."[46]
>
> ". . . to demonstrate that progress in science is not always easily achieved and is usually the result of modifying a theory to accommodate new information."[47]
>
> "We suggest that teachers should provide examples of the properties of a model that are both concrete and set in an historical context."[48]
>
> "We have taken time to present [. . .] in its historical context for several reasons. Perhaps the most important reason is so that you can appreciate the nature of science as a human activity."[49]

There are several reasons for introducing the history of science: a) it is interesting in itself; b) it presents certain pedagogical advantages that help in the understanding of concepts; and c) it illustrates the human aspect of science and the nature of scientific activity. However, only one textbook mentions the inherent attractiveness of the history of science to students:

> "Historical narratives are used to create interest in a topic."[50]

Another chooses to downplay any historical reference:

> "*Chemistry: Experiments and Principles* presents chemistry as it is today."[51]

Table VIII.11a-d presents data on the use of science history in textbooks. The information we sought centred both on the two extreme cases mentioned earlier (from the number of scientists mentioned to the number of case studies) and on examples in between (the names of scientists associated with a collaborative effort or with a particular methodology, for example). The table shows that all the textbooks used in the middle and senior years (except one) mention the names of scientists, with usually more names mentioned in the senior-years textbooks. Of 22 textbooks, 16 mostly use names merely to identify a fact, law or theory. In only six textbooks was the proportion of scientists, whose work was described according to a systematic account of the scientific method, greater than 50 per cent. Most often, the student is told of discoveries made by scientists but not the reasons why they were studying the particular phenomenon. Moreover, these scientists generally were not placed in any historical or social context.

Finally, despite the lip-service authors pay to scientific communication, their textbooks rarely mention the research team or communication network within which scientists work. The most representative case in this regard is the account of the development of the atomic model given in five chemistry textbooks[52] at the senior-years level. In each book, the student sees the development of this model from J.J. Thomson to Niels Bohr, including the corrections made by Ernest Rutherford and James Chadwick. At no time is the student given any indication that these men knew each other (and knew each other well) or that the atmosphere at the Cavendish Laboratory at Cambridge University contributed to these achievements (J.J. Thomson was director of the laboratory from 1884 to 1919 and Rutherford his student as of 1895, replacing him as director in 1919). Nor is there any mention that Niels Bohr had been a student of Thomson at Cambridge and of Rutherford at Manchester, and that Chadwick had worked under Rutherford at Cambridge. This is a prime example of "textbook science" in which historical events are presented outside their context and the scientists generally portrayed (often in biographies) as solitary geniuses who had the right idea at the right time.

This example raises another issue — the standardization of textbooks. None of the five textbooks differed significantly in describing the development of the atomic model. Moreover, we easily found other examples of how extensive this standardization was. All the textbooks, for example, used the Haber process for synthesizing ammonia to illustrate chemical equilibrium in the gaseous state, or its applications. What explanation can there be for this unanimous choice of examples? We also found it curious that textbook authors do not usually acknowledge their sources used in preparing their textbooks; *ALCHEM* is a rare exception to this. However, new editions of American textbooks such as *PSSC*, *CHEMStudy* and *BSCS*, do indicate that they are based on the original edition. Is it unreasonable to assume that these unacknowledged sources

Table VIII.11a – The History of Science in Science Textbooks – Middle Years, Biology (10)

Textbook code	11	12	13	14	15	16	17
Aims							
Inclusion of objective concerning history of science	X	?			X		
Scientists							
Total number of scientists mentioned	27	24	14	32	23	0	6
% of scientists mentioned merely to qualify a law, theory, etc.	19	46	100	46	57	0	100
% of scientists whose work is described according to "scientific method"	67	8	0	38	43	0	100
% of scientists associated with an historical or social context	56	4	0	16	13	0	100
% of scientists mentioned associated with a research team, information network, etc.	74	0	0	6	17	0	100
% of women scientists mentioned	0	0	0	0	0	0	0
Case Studies							
Case studies cited	X[a]	X[b]					
Illustrations or publications associated with history of science	0	0	0	1	1	0	7

[a] Spontaneous generation and cell theory.
[b] Discovery of a vitamin deficiency.

Table VIII.11b – The History of Science in Science Textbooks – Middle Years, Physical Sciences (20), General Science (30)

Textbook code	21	22	23	24	31	32	33
Aims							
Inclusion of objective concerning history of science	X			X[c]			
Scientists							
Total number of scientists mentioned	13	14	17	35	33	6[g]	8
% of scientists mentioned merely to qualify a law, theory, etc.	62	57	41	43	27	100	25
% of scientists whose work is described according to "scientific method"	15	43	59	22	6	33	75
% of scientists associated with an historical or social context	15	7	24	0	73	33	75
% of scientists mentioned associated with a research team, information network, etc.	0	14	6	0	0	0	0
% of women scientists mentioned	8	7	0	0	3[e]	0	0
Case Studies							
Case studies cited		X[a]	X[b]	X[d]	X[f]		
Illustrations or publications associated with history of science	0	2	1	1	0	0	6

[a] Law of definite proportions, development of periodic table, spectral analysis, discovery of radioactivity.
[b] Abandonment of caloric theory, measuring the speed of light, thermal energy and its conversions.
[c] Several of the great scientific ideas that have helped shape the world and will continue to do so.
[d] The structure of matter, the nature of heat.
[e] Marie Curie.
[f] Periodic classification and atomic model (partial treatment).
[g] About three sentences devoted to each scientist.

Table VIII.11c – The History of Science in Science Textbooks – Senior Years, Biology (40), Physics (60)

Textbook code	41	42	43	44	61	62	63	64
Aims								
Inclusion of objective concerning history of science	X	X				X		X
Scientists								
Total number of scientists mentioned	61	125	82	91	66	49	89	11
% of scientists mentioned merely to qualify a law, theory, etc.	62	30	65	16	41	84	30	82
% of scientists whose work is described according to "scientific method"	26	70	26	36	15	10	0	0
% of scientists associated with an historical or social context	8	33	34	14	0	0	0	18
% of scientists mentioned associated with a research team, information network, etc.	3	39	21	31	44	6	0	0
% of women scientists mentioned	12	5	1	6	3	2	2	0
Case Studies								
Case studies cited		X[a]	X[b]	X[c]			X[d]	
Illustrations or publications associated with history of science	3	1	3	0	34	0	31	0

[a] Origin of life, photosynthesis, Mendel, evolution, etc.
[b] Many biographies included.
[c] Evolution and natural selection.
[d] Solar system, forces and movement, photoelectric effect, etc.

Table VIII.11d – The History of Science in Science Textbooks – Senior Years, Chemistry (50)

Textbook code	51	52	53	54	55	56
Aims						
Inclusion of objective concerning history of science	([a])	X			X	X
Scientists						
Total number of scientists mentioned	26	61	69	50	30	35
% of scientists mentioned merely to qualify a law, theory, etc.	72	62	30	56	60	33
% of scientists whose work is described according to "scientific method"	28	33	29	24	40	16
% of scientists associated with an historical or social context	12	2	68	2	37	66
% of scientists mentioned associated with a research team, information network, etc.	12	20	38	18	0	20
% of women scientists mentioned	0	3	1	4	3	0
Case Studies						
Case studies cited	X[b]	X[c]			X[d]	X[e]
Illustrations or publications associated with history of science	2	0	0	0	6	2

[a] Many historical references and biographies of famous scientists are found throughout the program.
[b] History of the periodic table, development of the atomic model, Lavoisier and the beginnings of quantitative chemistry.
[c] Modern theory of combustion, discovery of radioactivity.
[d] Atomic model and periodic table (partial treatment).
[e] Atomic theory.

were usually other science textbooks and that this practice leads to textbook standardization?

We also wanted to know if any authors included case studies as part of their historical references, basing our definition of case study on the criteria proposed by Watson and Klopfer (see Appendix D). Table VIII.11 gives some idea of the use of case studies in textbooks and, consequently, of the extent to which students are offered a view of science different from "textbook science." In general, authors offer students case studies that do not necessarily conform to the criteria chosen (development of the atomic model is one example of this). The textbook with the most case studies is *Project Physics* (formerly *Harvard Project Physics*) by J. Rutherford *et al.* There is also a Canadian version by D. Paul *et al.* with large passages taken from the US version. It is interesting to note that Fletcher Watson, whose criteria we used to identify case studies, is one of this book's authors.

Table VIII.11 also shows that authors rarely include any illustrations or facsimiles of original publications. The woman scientist most often cited is Marie Curie. Very few Canadian scientists are mentioned, except in one biology textbook (44), which devotes several lines to a total of 14. Among the Canadian scientists mentioned in other books are Pierre Dansereau (13), Neil Bartlett (31 and 54), Sir Frederick Banting (52), R.J. Gillespie and Gerhard Herzberg (53), Sir Sandford Fleming (31) and Hans Selye (42).

In conclusion, if understanding the nature of science is one of the main objectives of science teaching, then should students and teachers not be well aware of the various messages concerning the nature of science found in textbooks? Is this "textbook science," which stems from a secondary textbook objective (the first being to convey science content) and from a general standardization of textbooks, an acceptable model? Do new policies such as the one in Québec – which requires authors to prepare textbooks in accordance with prescribed objectives – constitute a step away from standardization, or are other measures necessary? Is the "child as scientist" a proper model for teaching scientific thinking?

We are well aware that these questions are rather broad in scope, as might be expected when dealing with the problem of the nature of science as represented in textbooks. Perhaps much of the problem stems from an evident lack of interest on the part of researchers to study science textbooks partly because of its apparent difficulty and partly because in North America, textbooks sometimes suffer from the emphasis placed on "active" teaching methods and on the individualization of teaching, in which the textbook's role is not considered essential.[53] The survey, however, as well as our examination of what occurs in science classrooms, show that the textbook does play an important role, and we believe that a greater understanding of its impact on students and on their learning is important for both educational policymaking and practice.

Appendices

Appendix A – Science Curriculum Policy Documents

All ministries of education supplied the study with policy documents concerning their science programs. However, only those required for analysis purposes are listed here. The list does not, therefore, represent a complete inventory of all provincial science program documents.

Early Years

Newfoundland
Philosophy and Objectives for Science Education in Newfoundland Schools, Grades K-11 (1978)
Elementary Science Course Description (1978)

Prince Edward Island
A Style for Every Child: Program of Studies and Related Information for the Schools of Prince Edward Island (1977-78) (amended — 1978)
Science Activities in the Elementary School, Years I-VI

Nova Scotia
Science in the Elementary School: A Teaching Guide (1978)

New Brunswick
Program in Elementary School Science (1977)
Programme-cadre, sciences à l'élémentaire (1977)
Guide pédagogique, sciences à l'élémentaire, Premier cycle (1970); *Deuxième cycle* (1977)

Québec
L'école québecoise, énoncé de politique et plan d'action (1979)
Programme d'étude, primaire, sciences de la nature (1980)

Matériel didactique agréé par le ministère de l'Éducation pour les écoles primaires de langue française (1979); *Supplément* (1981)
Educational materials approved by the ministère de l'Éducation for use in English-language elementary schools (1979); *Supplement* (1981)

Ontario
The Formative Years (1975)
Circular 14: Textbooks (1982)

Manitoba
K-6 Science (1979)

Saskatchewan
Division I Science Program (1971)
Curriculum Guide for Division II Science (1971)

Alberta
Curriculum Guide for Elementary Science (1980 — interim)

British Columbia
Elementary Science: Curriculum Guide (1981)
Prescribed and Authorized Learning Materials: Grades K-XII (1979)

Northwest Territories
Elementary Science Program: Interim Edition (1978)

Yukon Territory
The Exploring Science Program Teacher's Guide (1978)

Middle Years

Newfoundland
Philosophy and Objectives for Science Education in Newfoundland Schools, Grades K-11 (1978)
Junior High Science Curriculum Guide (1980)

Prince Edward Island
A Style for Every Child: Program of Studies and Related Information for the Schools of Prince Edward Island (1977-78, amended 1978)
Levels Seven, Eight, Nine Science Discovery Approach: A Suggested Program for P.E.I. Schools

Nova Scotia
Science in the Junior High School (1977)

New Brunswick
Junior High Science (1980)
Sciences, secondaire, premier cycle (1979)

Québec
Programme d'étude, secondaire
Écologie 176-113
Initiation à la biologie humaine 175-133 (documents de travail, 1980)
Matériel didactique agréé par le ministère de l'Éducation pour les écoles secondaires de langue française (1979); *Supplément* (1981)
Educational materials approved by the ministère de l'Éducation for use in English-language secondary schools (1979); *Supplement* (1981)

Ontario
Intermediate Division Science (1978)
Circular 14: Textbooks (1982)

Manitoba
7-9 Science (1979)

Saskatchewan
A Curriculum Guide for Division III Science (1979)

Alberta
Curriculum Guide for Junior High School Science (1978)

British Columbia
Junior Secondary Science, Curriculum/Resource Guide, 8-10 (Draft, 1982)

Northwest Territories
Middle Years Science (1979)

Senior Years

Newfoundland
Philosophy and Objectives for Science Education in Newfoundland Schools, Grades K-11 (1978)
High School Biology Curriculum Guide (1979)
Biology 2201 (1981)
Biology 3201 (1982)
Chemistry 2202 (1982)
High School Physics Course Description (1979)
Physics 2204 (1981)
Physics 3204 (1982)

Prince Edward Island
A Style for Every Child: Program of Studies and Related Information for the Schools of Prince Edward Island (1977-78, amended — 1978)

Nova Scotia
Biology 010, 310, 012, 312 — A Teaching Guide (1978)
Chemistry 011, 012, 311, 312 — A Teaching Guide (1977)
Physics 011, 012, 311, 312 — A Teaching Guide (1977)

New Brunswick
Biology 102-101 (1980)
Biology 103 (1977)
Biology 122 (1977)
Chemistry 111-121 (1979)
Chemistry 112-122 (1979)
Physics 111-121 (1969)
Physics 112-122 (1979)
Plans d'études:
Biologie 102-122 (1972)
Chimie I and II (1980)
Physique 112-122 (1974)

Québec
Programmes d'études des écoles secondaires, Biologie 422 (1971)
Chimie 270-442, 270-462, 270-562 (1976)
Physique 181-643, 181-653 (1980)
Matériel didactique agréé par le ministère de l'Éducation pour les écoles secondaires de langue française (1979); *Supplément* (1980)
Educational materials approved by the ministère de l'Éducation for use in English-language secondary schools (1979); *Supplement* (1980)

Ontario (no senior-years guidelines available)
Circular 14: Textbooks (1982)

Manitoba
Biology 200-300 — pilot program (1981)
Chemistry 200-300 — pilot program (1981)
Physics 200-300 — pilot program (1981)

Saskatchewan
Biology 20,30 (1971); *Supplement* (1979)
Chemistry 20,30 (1976)
Physics 20,30 (1976); *Supplement* (1979)

Alberta
Biology 10-20-30 (1977)
Chemistry 10-20-30 (1977)
Physics 10-20-30 (1977)

British Columbia
Biology 11 and 12 (1974)
Chemistry 11: Learning Outcomes and Resource Guide (1977)
Chemistry 12: Learning Outcomes and Resource Guide (1978)
Physics 11: Curriculum Guide (1981)
Prescribed and Authorized Learning Materials: Grades K-11 (1979)

Appendix B – Science Textbooks

Books listed here are those listed by ministry documents as prescribed, approved or authorized for use by students. Only books and series are listed (i.e., not "kits" of equipment or audiovisual packages). Also only those that cover a significant proportion of a course are identified (not, for example, single-topic books). Owing to the co-existence of more than one edition of certain texts, only the dates of the first and the most recent editions are specified. Books are listed in alphabetical order by titles within each of the following sections:

A. Early Years

B. Middle Years

C. Senior Years: C1. Biology
C2. Chemistry
C3. Physics

Where a book is listed or used for more than one level or subject, it is placed at the level (and subject) where it is most often used and marked with an asterisk.

For each book listed, the following information is provided in the five numbered columns on the right-hand side:

1. The number of provinces listing the book;
2. The number of provinces in which survey respondents have reported the book as being in use;
3. The number of survey respondents reporting the book as being in use;
4. X indicates that teacher assessments of the book have been collated;
5. X indicates that the book has been analyzed as part of the study.

A. Early Years	1	2	3	4	5
Apprentissage de la pensée scientifique (Collection APS) American Association for the Advancement of Science Traduit, Bureau de recherche et de consultation en éducation Beauchemin, 1971	1	1	11		
Les chemins de la science V. Rockcastle et coll. Traduit et adapté, F. Séguin Éditions du Renouveau Pédagogique, 1978	6	7	54	X	X

	1	2	3	4	5
Concepts in Science P. Brandwein *et al.* Longman, 1968-1980 (3 eds.)	1	4	21	X	
Elementary Science Study (ESS) Education Development Center McGraw-Hill, 1967-70	3	0	0		
Energy Literacy Series S.E.E.D.S. Foundation SRA, 1981	4	0	0		
ESS (Collection) Education Development Center (traduit) McGraw-Hill, 1967-71	2	0	0		
Étude de ton environnement J.-C. MacBean et coll. Traduit, I. Sabourin Adapté, R. Gervais et D. Sénécal Holt, Rinehart & Winston, 1973-77 (2 eds.)	2	0	0		
*Étudie ton milieu** F. Miron et coll. McGraw-Hill Ryerson, 1974	3	0	0		
L'éveil de l'enfant par les activités scientifiques R. Tavernier Bordas Dunod, 1976-78 (2 eds.)	1	0	0		
Examining Your Environment (EYE) J.C. MacBean *et al.* Holt, Rinehart & Winston, 1977	5	2	2		
Experiences in Science H.E. Tannenbaum *et al.* McGraw-Hill, 1966	1	0	0		
Heath Science Series H. & N. Schneider Copp Clark, 1968	2	4	13	X	
Investigating Science Series L.A. Cole *et al.* The Book Society of Canada, 1962	1	0	0		

	1	2	3	4	5
J'observe la nature (Collection) A. Bultreys Traduit, J. Razée Granger Frères, 1976	1	0	0		
Laidlaw Exploring Science Program M.K. Blecha *et al*, Doubleday, 1977-79 (3 eds.)	4	5	121	X	X
Laidlaw Modern Science, Levels 1-6 H.A. Smith and M.K. Blecha Doubleday, 1976	2	1	7		
Modern Elementary Science A.S. Fischler *et al.* Holt, Rinehart & Winston, 1971	2	2	8		
Modular Activities Program in Science/ MAPS C. Berger *et al.* Houghton Mifflin, 1974-77 (2 eds.)	2	2	11	X	
*Le monde qui t'entoure** S. Rouleau et M. Demers Guérin, 1976	2	0	0		
Our Science Program R.H. Horwood *et al.* Gage, 1969-77	2	0	0		
Science 5/13 (Learning Through Science) L. Ennever, Project Director MacDonald Educational/GLC, 1973-81	4	3	3		
Science Curriculum Improvement Study (SCIS) W. Thier *et al.* Gage, 1978	3	0	0		
Science in Action I. Woolley, editor McGraw-Hill Ryerson, 1975-76	3	3	3		
Science Involvement Program D. Gladstone and J.R. Gladstone Maclean-Hunter Learning Materials, 1972	1	0	0		
Science Reader 3-9 F.M. Branley Reader's Digest, 1974	1	0	0		

	1	2	3	4	5
Science - A Process Approach (SAPA) American Association for the Advancement of Science Xerox-Ginn, 1974-77 (2 eds.)	2	0	0		
Science: Understanding Your Environment G.G. and J.B. Mallinson *et al.* Silver Burdett, 1978	1	1	11		
Le secret des choses: Initiation aux sciences (SCIS) Traduit et adapté, J.-M. Chevrier et coll. Institut de Recherches Psychologiques, 1970-79	1	1	8		
Self-Paced Investigations For Elementary Science (SPIES) G. Katagiri *et al.* Silver Burdett/GLC, 1976	1	0	0		
Space, Time, Energy, Matter (STEM) V. Rockcastle *et al.* Addison-Wesley, 1977-80 (2 eds.)	10	11	529	X	X
Wedge Resources C. Anastasiou, Director Western Educational Development Group, 1973-79	1	0	0		
Young Scientist Series J.G. Navarra and J. Zafforoni Harper & Row/Fitzhenry & Whiteside, 1971	1	0	0		

B. Middle Years

	1	2	3	4	5
Biological Sciences: An Introductory Study W. Andrews *et al.* Prentice-Hall, 1980	3	3	49	X	X
Biologie humaine C. Désiré et coll. Centre Éducatif et Culturel, 1968	1	1	6	X	X
Biologie humaine P. Thibault Éditions Hurtubise HMH, 1979	1	1	4		

	1	2	3	4	5
Challenges to Science: Earth Science R.L. Heller *et al.* McGraw-Hill Ryerson, 1976	2	1	9		
Challenges to Science: Life Science W.L. Smallwood McGraw-Hill Ryerson, 1972	2	1	11	X	
Challenges to Science: Physical Science R.L. Heller *et al.* McGraw-Hill Ryerson, 1979	2	0	0		
Concepts and Challenges in Science A. Winkler *et al.* Gage, 1979	6	9	13	X	
Developing Science Concepts in the Laboratory M.C. Schmid and M.T. Murphy Prentice-Hall, 1968-79 (2 eds.)	2	2	109	X	X
*Earth Science** W.L. Ramsey *et al.* Holt, Rinehart & Winston, 1978	2	2	10	X	
Écologie E.P. Odum Éditions HRW, 1976	1	0	0		
*Écologie, initiation à la biologie** É. Magnin McGraw-Hill, 1975	3	0	0		
Energy, Matter and Change R.D. Townsend and P. Hurd Scott, Foresman, 1973	2	2	4		
Les ètres et leur milieu M. Poirier et G. Viscasillas Brault et Bouthillier, 1970	1	3	10	X	X
Exploring Matter and Energy M.K. Blecha *et al.* Doubleday Canada, 1978	1	6	35	X	X
Exploring Science Series W.A. Thurber and R.E. Kilburn Macmillan, 1977	5	7	75	X	X

	1	2	3	4	5
*Extending Science Concepts in the Laboratory** W.H. Rasmusson and M.C. Schmid, editors Prentice-Hall, 1970	2	2	98	X	
Focus on Earth Science M.S. Bishop *et al.* Charles E. Merrill, 1976-1981 (4 eds.)	2	4	7		
Focus on Life Science C.H. Heimler and J.D. Lockard Charles E. Merrill, 1977-81 (4 eds.)	1	3	15	X	X
Focus on Physical Science C.H. Heimler *et al.* Charles E. Merrill, 1969-81 (4 eds.)	1	0	0		
Focus on Science: Exploring the Natural World D. Gough and F. Flanagan D.C. Heath, 1980	4	2	7		X
Focus on Science: Exploring the Physical World F. Flanagan D.C. Heath, 1979	4	2	3		
From Nature to Man B.L. Barrett and J.N. Stratton Wiley, 1976	1	0	0		
Ideas and Investigations in Science H. Wong and M. Dolmatz Prentice-Hall, 1978-82 (2 eds.)	2	3	4		
Individualized Science Instructional System (ISIS) E. Burkman Ginn, 1980	3	2	13		
Initiation aux sciences physiques (ISP) U. Haber-Schaim et coll. Traduit et adapté, J.M. Chevrier et coll. Institut de Recherches Psychologiques, 1969-78 (2 eds.)	3	2	12	X	X
Interactions of Earth and Time N. Abraham *et al.* Rand McNally, 1979	1	1	2		

	1	2	3	4	5
Interaction of Man and Biosphere N. Abraham *et al.* Rand McNally, 1969	1	2	3		
Introducing Science Concepts in the Laboratory M.C. Schmid and M.T. Murphy Prentice-Hall, 1973-77 (2 eds.)	3	2	91	X	X
*Introduction à la biologie** P. Thibeault et R. D'Aoust Éditions Hurtubise HMH, 1970	4	2	15	X	X
Introduction aux sciences expérimentales M. Noiseaux Éditions Sciences et Culture, 1971-78 (2 eds.)	1	0	0		
Introduction aux sciences physiques W.A. Andrews *et al.* Traduit et adapté, J. Deschênes Éditions Études Vivantes, 1979	2	0	0		
Introductory Physical Science U. Haber-Schaim *et al.* Prentice-Hall, 1967-82 (4 eds.)	2	2	2		
Investigating Life Science M. O'Flanagan and G. Connelly Holt, Rinehart & Winston, 1980	1	0	0		
Investigating Physical Science M. O'Flanagan Holt, Rinehart, & Winston, 1981	1	0	0		
Investigating the Earth American Geological Institute Houghton Mifflin, 1973-81 (7 eds.)	4	3	7		
Investigations in Science: A Modular Approach J.K. Olson *et al.* Wiley, 1974-77 (2 eds.)	1	2	3		
Life Science W.L. Ramsey *et al.* Holt, Rinehart & Winston, 1978	1	1	1		

	1	2	3	4	5
Life Science: A Problem Solving Approach J.L. Carter *et al.* Ginn, 1974-77 (2 eds.)	1	3	10	X	X
Methods of Science Today G. Erwin *et al.* Clarke, Irwin, 1979	1	2	34	X	
Modern Life Science F.L. Fitzpatrick and J.W. Hole Holt, Rinehart & Winston, 1974	1	1	1		
Modern Physical Science G.R. Tracy *et al.* Holt, Rinehart & Winston, 1970	1	1	1		
*Pathways in Science** J.M. Oxenhorn Globe/Modern, 1978	3	4	15		
Physical Science W.L. Ramsey *et al.* Holt, Rinehart & Winston, 1978	1	1	5		
Physical Science: A Basis for Understanding J.E. Garden and M.J. Gadsby Wiley, 1980	1	0	0		
Physical Science: A Problem Solving Approach J.L. Carter *et al.* Ginn, 1974	2	3	10	X	
Physical Science: An Introductory Study W. Andrews *et al.* Prentice-Hall, 1978	5	5	87	X	X
Physical Science: Interaction of Matter and Energy R.W. Heath and R.R. McNaughton D.C. Heath, 1976	4	4	8		
Physical Science Investigations C.L. Bickel *et al.* Houghton Mifflin, 1973-79 (2 eds.)	2	0	0		
*Précis de biologie humaine** T.F. Morrison *et al.* Traduit, A. Décarie Éditions HRW, 1977	2	1	1		

	1	2	3	4	5
Principles of Science C.H. Heimler and C.D. Neal Charles E. Merrill, 1975-83 (4 eds.)	1	3	9		
Reading About Science C. Anastasiou *et al.* Holt, Rinehart & Winston, 1970	2	1	3		
Science Networks: Biology O.J. Mardall *et al.* Globe/Modern, 1981	2	0	0		
Sciences physiques J.-M. Chevrier *et coll.* Institut de Recherches Psychologiques, 1971-73 (2 eds.)	1	0	0		
Sciences physiques et biologiques H. Wong Traduit, N. Boudreau Éditions Hurtubise HMH, 1973	1	0	0		
Sciences physiques: matière, énergie, interactions R.R. MacNaughton et R.W. Heath Traduit et adapté, J. Bergeron et M. Mercure Centre Éducatif et Culturel, 1977	3	2	3		X
Scienceways J. MacBean *et al.* Copp Clark Pitman, 1979-80	4	3	46	X	X
*Searching for Structure** D.H. Pike, General Editor Holt, Rinehart & Winston, 1974-78	4	3	93	X	
Spaceship Earth J.J. Jackson and E.D. Evans Houghton Mifflin, 1973-80 (2 eds.)	2	1	1		

C. Senior Years

C1. Biology

Biological Science D. Galbraith *et al.* Holt, Rinehart & Winston, 1978	1	1	7		

	1	2	3	4	5
Biological Science W.H. Gregory and E.H. Goldman Ginn, 1971	1	1	2		
Biological Science: An Ecological Approach Biological Sciences Curriculum Study Rand McNally, 1963-78 (4 eds.)	6	5	57	X	X
Biological Science: An Inquiry Into Life Biological Sciences Curriculum Study Harcourt, Brace, Jovanovich/Longman, 1963-80 (4 eds.)	2	4	8	X	
Biological Science: Molecules to Man Biological Sciences Curriculum Study Houghton Mifflin, 1973	1	2	12	X	
Biologie L. Cournoyer et O. Garon Éditions Hurturbise HMH, 1969	2	0	0		
Biologie 412 & 422 G. Llull Guérin, 1973	2	0	0		
Biologie 5e et 6e J.-P. Astolfi et coll. Librairie Bélin, 1978	1	0	0		
Biologie, des molécules à l'homme Biological Sciences Curriculum Study Traduit, J.L. Tremblay Leméac, 1966	1	1	2		
Biology J.W. Kimball *et al.* Addison-Wesley, 1965-78 (4 eds.)	2	2	20	X	X
Biology: An Inquiry into the Nature of Life S.L. Weinberg Allyn & Bacon, 1966-81 (5 eds.)	1	1	1		
Biology: Living Systems R.F. Oram *et al.* Charles E. Merrill, 1969-83 (4 eds.)	1	2	36	X	
Bodyworks: Your Human Biology H.R. Scarrow Globe/Modern, 1979	2	0	0		

	1	2	3	4	5
Foundations of Biology W. McElroy *et al.* Prentice-Hall Canada, 1968	6	5	34	X	X
L'homme dans son milieu P. Couillard et coll. Guérin 1968	2	0	0		
Inquiries into Biology H.M. Lang *et al.* Gage, 1974	1	0	0		
Investigations in Biology G. Benson *et al.* Addison-Wesley, 1977	1	0	0		
Investigations of Cells and Organisms P. Abramoff and R. Thomson Prentice-Hall Canada, 1968	6	1	1		
Living Things H.E. Teter, T.D. Bain, and F.L. Fitzpatrick Holt, Rinehart & Winston, 1977	1	2	3		
Modern Biology J.J. Otto and A. Towle Holt, Rinehart & Winston, 1965-82 (6 eds.)	5	5	70	X	X
*Pathways in Biology** J.M. Oxenhorn Globe/Modern Curriculum Press, 1977	2	4	6		
Les sciences par objectifs de comportement, biologie Le Groupe SO_2 Éditions du Renouveau Pédagogique, 1976-78	2	1	1		
Understanding Living Things J. Reimer and W. Wilson D.C. Heath, 1977	2	2	6	X	X

C2. Chemistry	1	2	3	4	5
A la découverte de la chimie E. Ledbetter et J. Young Traduit, B. Sicotte Éditions du Renouveau Pédagogique, 1975	2	2	4		
Action Chemistry K. Ashcroft The Book Society of Canada, 1974	2	1	1		
ALCHEM F. Jenkins *et al.* J.M. LeBel, 1978	4	2	14	X	X
Basic Modern Chemistry S. Madras McGraw-Hill Ryerson, 1965-78 (3 eds.)	2	1	1		
Chemistry G.R. Choppin *et al.* Silver Burdett/GLC, 1935-78 (12 eds.)	1	0	0		
Chemistry: A Modern Course R. Smoot *et al.* Charles E. Merrill, 1962-83 (6 eds.)	1	1	2		
Chemistry: An Experimental Science G. Pimentel *et al.* W.H. Freeman, 1963	1	3	8	X	
Chemistry: An Investigative Approach F.A. Cotton *et al.* Houghton Mifflin/Nelson, 1970-80 (2 eds.)	1	2	2		
Chemistry: Experimental Foundations R.W. Parry *et al.* Prentice-Hall, 1970-82 (3 eds.)	4	5	23	X	X
Chemistry: Experiments and Principles P.R. O'Connor *et al.* D.C. Heath, 1968-82 (4 eds.)	6	6	26	X	X
Chemistry Today R.L. Whitman and E.E. Zinck Prentice-Hall Canada, 1976-82 (2 eds.)	3	3	30	X	X

	1	2	3	4	5
Chimie, apprentissage individualisé F. Morin et B. Joseph Éditions Hurtubise HMH, 1976-78	1	1	1		
La chimie en action K. Ashcroft et coll. The Book Society of Canada, 1981	1	0	0		
La chimie: Science expérimentale G. Pimentel et coll. Traduit, G. Plante et coll. Leméac, 1966	1	1	6		
La chimie: Expériences et principes P.R. O'Connor et coll. Traduit, J. Leclerc Centre Éducatif et Culturel, 1974-79 (3 eds.)	2	1	7	X	
Éléments de chimie expérimentale R. Lahaie et coll. Holt, Rinehart & Winston, 1974	2	2	15	X	X
Éléments de chimie moderne G. Hall et S. Madras Traduit, J.-P. Gravel McGraw-Hill, 1965-81 (3 eds.)	3	4	6		
Elements of Experimental Chemistry R. Lahaie *et al.* Translated, N. Ouzounian *et al.* Holt, Rinehart & Winston, 1978	2	1	1		
Foundations of Chemistry E.R. Toon and G.L.Ellis Holt, Rinehart & Winston, 1973-78 (2 eds.)	4	4	30	X	
Inquiries in Chemistry A.M. Turner and C.T. Sears Allyn & Bacon, 1974-77 (3 eds.)	4	3	40	X	
Interaction of Matter and Energy N. Abraham *et al.* Rand McNally, 1979	1	3	8	X	
Introductory Experimental Chemistry M.B. Messer *et al.* Prentice-Hall, 1977	1	1	1		

	1	2	3	4	5
Investigative Science J. Hand *et al.* Gage, 1977-78	1	0	0		
Keys to Chemistry E. Ledbetter and J. Young Addison-Wesley, 1977	5	6	14	X	X
MAC: A Modular Approach to Chemistry D.A. Humphreys and A.C. Blizzard Wiley, 1976-78	1	0	0		
Modern Chemistry J. Metcalfe *et al.* Holt, Rinehart & Winston, 1958-82 (6 eds.)	1	5	21	X	
The Nature of Matter D. Courneya and H. McDonald D.C. Heath, 1976	4	1	8		
Outlines of Chemistry R.P. Graham and W.A.E. McBryde Clarke, Irwin, 1978	1	1	3		
Les sciences par objectifs de comportement, chimie Le Groupe SO_2 Éditions du Renouveau Pédagogique, 1978	3	0	0		

C3. Physics

	1	2	3	4	5
Basic Physics for Secondary Schools H.L. Eubank *et al.* Gage, 1963	2	0	0		
Concepts in Physics F. Miller *et al.* Academic Press, 1974-80 (3 eds.)	1	0	0		
Éléments de physique M. Benoit et coll. Beauchemin, 1963-66 (2 eds.)	1	2	2		
Fundamentals of Physics R.W. Heath *et al.* D.C. Heath, 1979	6	5	53	X	X

	1	2	3	4	5
Ideas of Physics D.C. Giancoli Academic Press, 1978-81	1	0	0		
Matière et énergie J.H. MacLachlan et coll. Traduit et adapté, P. Marcotte Guérin, 1981	1	0	0		
Matter and Energy J.H. MacLachlan *et al.* Clarke, Irwin, 1977	1	1	26	X	X
Modern Physics C.E. Dull *et al.* Holt, Rinehart & Winston, 1963-80 (6 eds.)	1	0	0		
Modern Physics J.E. Williams *et al.* Holt, Rinehart & Winston, 1972	1	0	0		
Physics D.C. Giancoli Prentice-Hall, 1980	2	0	0		
Physics (PSSC) U. Haber-Schaim *et al.* D.C, Heath, 1960-81 (5 eds.)	6	6	48	X	X
Physics: A Human Endeavour D. Paul *et al.* Holt, Rinehart & Winston, 1976-77	7	5	36	X	X
Physics: A Practical Approach A.J. Hirsch Wiley, 1981	1	0	0		
Physics: An Energy Introduction G. Laundry *et al.* McGraw-Hill Ryerson, 1979	1	0	0		
Physics: Its Methods and Meaning A. Taffel Allyn & Bacon, 1969-81 (3 eds.)	1	1	4		
Physics: Principles and Problems J.T. Murphy and R.C. Smoot Charles E. Merrill, 1972-82 (3 eds.)	2	2	3		

	1	2	3	4	5
Physics: The Fundamental Science O.C. Barton and R.J. Raymer Holt, Rinehart & Winston, 1967	2	2	5		
Physique R. St-Laurent Éditions Science Moderne, 1975	1	0	0		
La physique au secondaire par objectifs opérationnels M. Do et R. Descoteaux Guérin, 1976-77	2	0	0		
La physique en classe laboratoire M. Benoit et coll. Beauchemin, 1974	1	0	0		
Physique HPP J. Rutherford Traduit et adapté, L. Sainte-Marie Institut de Recherches Psychologiques, 1978-79	1	1	2		
La physique par la redécouverte dirigée J. Desautels et P.-L. Trempe Éditions Sciences et Culture, 1972	1	0	0		
Physique (PSSC) U. Haber-Schaim et coll. Traduit et adapté, P. Tougas Centre Éducatif et Culturel, 1974-75 (2 eds.)	1	3	8	X	
Physique. . . mais c'est simple P.-L. Trempe Éditions Sciences et Culture, 1971	1	0	0		
Physique: Science de l'univers O.C. Barton et R.J. Raymer Éditions HRW, 1970-79 (2 eds.)	1	1	1		
Physique, science expérimentale J. Désautels et coll. Éditions Sciences et Culture, 1968-1970	1	0	0		
Project Physics J. Rutherford *et al.* Holt, Rinehart & Winston, 1971	3	2	8	X	

	1	2	3	4	5
Les sciences par objectifs de comportement, physique Le Groupe SO_2 Éditions du Renouveau Pédagogique, 1974	2	0	0		
Sciences physique II Équipe IPS Traduit et adapté, équipe IRP Institut de Recherches Psychologiques, 1976	1	0	0		
Secondary Physics Outlines E.O. James A. Wheaton/Pergamon, 1975	1	0	0		
The World of Physics R.I. Hulsizer and D. Lazarus Addison-Wesley, 1972	1	0	0		
Thèmes Vuibert (physique) H.F. Boulind et coll. Librairie Vuibert, 1974	1	0	0		

Appendix C – Teachers' Assessments of Science Textbooks

Detailed Results of Assessment

For each textbook in the sample, the reader will find the following information: title, author(s), publisher, the number of users responding to the survey and their geographical distribution. To facilitate reading of the assessment results, we have made a few editorial changes in the data presentation. For each of the 10 features listed below teachers were asked to respond using a number from 1 to 4 to represent their assessment:

1. Completely inadequate
2. Fairly inadequate
3. Fairly adequate
4. Completely adequate

We have combined these responses to produce two judgements as follows:

1 + 2 = I (Fairly or Completely Inadequate)
3 + 4 = II (Fairly or Completely Adequate)

Each line of the assessment table contains the following information (from left to right):

1. The feature being assessed (lines 1-10) and an overall impression (line 11);
2. the number of respondents assessing this feature;
3. percentage of responses in category I (inadequate);
4. percentage of responses in category II (adequate);
5. the ranking of this feature (R) on an "adequacy scale" from 1 (most adequate feature) to 10 (least adequate feature).

As the reader will see, the number of respondents assessing each feature (N) varies considerably from book to book (from a low of 5 to a high of 408). It is not, therefore, possible to claim that this assessment of some of the textbooks is representative of all teachers in Canada who use the books.

Title: *Les chemins de la science*
Author(s): Verne N. Rockcastle *et al.*, French version of *STEM*, translated and adapted by Fernand Séguin
Publisher: Éditions du Renouveau Pédagogique
Number of users responding to survey: 54
Geographical distribution of respondents: NS (11), Qué. (8), Ont. (6), Man. (15), Sask. (3), Alta. (9), NWT (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	49	33	67	4
The relationship of the text's objectives with your own priorities	50	24	76	3
Readability for students	50	68	32	8
Illustrations, photographs, etc.	50	18	82	2
Suggested activities	50	36	64	5
Canadian examples	49	39	61	6
Accounts of the applications of science	50	40	60	7
Appropriateness for slow students	50	76	24	10
Appropriateness for bright students	50	10	90	1
References for further reading	50	74	26	9
Overall impression	50	48	52	

Comment: The assessment of the French version by francophone respondents differs significantly from that of the English version assessed by anglophone respondents.

Title: *Concepts in Science*
Author(s): Paul Brandwein, W. Yasso and D. Brovey
Publisher: Longman
Number of users responding to survey: 21
Geographical distribution of respondents: Man. (3), Sask. (2), Alta. (15), BC (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	16	44	56	5
The relationship of the text's objectives with your own priorities	16	25	75	1
Readability for students	16	50	50	7
Illustrations, photographs, etc.	16	25	75	1
Suggested activities	16	37	63	4
Canadian examples	16	56	44	9
Accounts of the applications of science	16	50	50	7
Appropriateness for slow students	16	62	38	10
Appropriateness for bright students	16	31	69	3
References for further reading	16	44	56	5
Overall impression	16	50	50	

Title: *Heath Science Series, Science in Your Life, Science in Your World*
Author(s): H. & N. Schneider
Publisher: Copp Clark
Number of users responding to survey: 13
Geographical distribution of respondents: PEI (1), NS (3), Man. (1), Sask. (8)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	12	42	58	3
The relationship of the text's objectives with your own priorities	11	54	46	5
Readability for students	11	45	55	4
Illustrations, photographs, etc.	11	36	64	1
Suggested activities	11	36	64	1
Canadian examples	11	91	9	10
Accounts of the applications of science	11	64	36	8
Appropriateness for slow students	11	73	27	9
Appropriateness for bright students	11	54	46	5
References for further reading	11	54	46	5
Overall impression	11	45	55	

Title: *Laidlaw Exploring Science Program*
Author(s): Milo K. Blecha *et al.*
Publisher: Doubleday Canada Ltd.
Number of users responding to survey: 121
Geographical distribution of respondents: NS (2), Sask. (8), Alta. (11), BC (76), YT (24)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	96	13	87	2
The relationship of the text's objectives with your own priorities	96	25	75	3
Readability for students	96	26	74	4
Illustrations, photographs, etc.	96	10	90	1
Suggested activities	96	27	73	5
Canadian examples	94	42	58	9
Accounts of the applications of science	91	34	66	8
Appropriateness for slow students	93	61	39	10
Appropriateness for bright students	92	31	69	7
References for further reading	92	30	70	6
Overall impression	91	16	84	

Comment: This assessment covers a series of six books designed for students from grade 1 through grade 7.

Title: *Modular Activities Program in Science (MAPS)*
Author(s): Carl Berger *et al.*
Publisher: Houghton Mifflin
Number of users responding to survey: 11
Geographical distribution of respondents: Man. (8), Alta. (3)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	8	25	75	7
The relationship of the text's objectives with your own priorities	7	29	71	8
Readability for students	6	33	67	9
Illustrations, photographs, etc.	7	14	86	5
Suggested activities	7	0	100	1
Canadian examples	6	0	100	1
Accounts of the applications of science	7	0	100	1
Appropriateness for slow students	8	50	50	10
Appropriateness for bright students	7	0	100	1
References for further reading	6	17	83	6
Overall impression	7	14	86	

Title: *Space, Time, Energy, Matter (STEM)*
Author(s): Verne N. Rockcastle *et al.*
Publisher: Addison-Wesley
Number of users responding to survey: 529
Geographical distribution of respondents: Nfld. (162), NS (52), NB (49), Qué. (3), Ont. (2), Man. (42), Sask. (46), Alta. (91), BC (36), YT (1), NWT (45)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	408	19	81	2
The relationship of the text's objectives with your own priorities	407	23	77	4
Readability for students	404	26	74	6
Illustrations, photographs, etc.	405	16	84	1
Suggested activities	403	24	76	5
Canadian examples	382	44	56	8
Accounts of the applications of science	393	30	70	7
Appropriateness for slow students	398	50	50	10
Appropriateness for bright students	398	21	79	3
References for further reading	390	44	56	8
Overall impression	402	19	81	

Comment: This assessment covers a series of seven books designed for students from kindergarten through grade 6.

Title: *Biological Science: An Introductory Study*
Author(s): William Andrews *et al.*
Publisher: Prentice-Hall
Number of users responding to survey: 49
Geographical distribution of respondents: NB (5), Ont. (40), BC (4)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	43	12	88	3
The relationship of the text's objectives with your own priorities	43	19	81	5
Readability for students	43	19	81	5
Illustrations, photographs, etc.	43	7	93	1
Suggested activities	43	16	84	4
Canadian examples	41	32	68	7
Accounts of the applications of science	42	40	60	8
Appropriateness for slow students	43	91	9	10
Appropriateness for bright students	43	9	91	2
References for further reading	43	46	54	9
Overall impression	43	14	86	

Title: *Biologie Humaine*
Author(s): Désiré, Marchal and Bélanger
Publisher: Centre Éducatif et Culturel
Number of users responding to survey: 6
Geographical distribution of respondents: Qué. (6)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	6	50	50	3
The relationship of the text's objectives with your own priorities	6	67	33	5
Readability for students	6	67	33	5
Illustrations, photographs, etc.	6	0	100	1
Suggested activities	6	83	17	7
Canadian examples	6	83	17	7
Accounts of the applications of science	6	50	50	3
Appropriateness for slow students	6	83	17	7
Appropriateness for bright students	6	33	67	2
References for further reading	6	100	0	10
Overall impression	6	83	17	

Title: *Challenges to Science: Life Science*
Author(s): W.L. Smallwood
Publisher: McGraw-Hill Ryerson
Number of users responding to survey: 11
Geographical distribution of respondents: Alta. (11)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	9	11	89	2
The relationship of the text's objectives with your own priorities	8	12	86	3
Readability for students	8	12	86	3
Illustrations, photographs, etc.	8	0	100	1
Suggested activities	8	62	38	7
Canadian examples	9	78	22	9
Accounts of the applications of science	9	33	67	6
Appropriateness for slow students	7	86	14	10
Appropriateness for bright students	8	25	75	5
References for further reading	8	75	25	8
Overall impression	8	12	88	

Title: *Concepts and Challenges in Science*
Author(s): Alan Winkler *et al.*
Publisher: Gage
Number of users responding to survey: 9
Geographical distribution of respondents: Nfld. (1), PEI (2), Qué. (1), Man. (2), Alta. (1), NWT (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	7	14	86	1
The relationship of the text's objectives with your own priorities	7	29	71	4
Readability for students	7	14	86	1
Illustrations, photographs, etc.	7	14	86	1
Suggested activities	7	29	71	4
Canadian examples	6	67	33	9
Accounts of the applications of science	7	43	57	7
Appropriateness for slow students	7	29	71	4
Appropriateness for bright students	7	57	43	8
References for further reading	7	71	29	10
Overall impression	7	14	86	

Title: *Developing Science Concepts in the Laboratory*
Author(s): M.C. Schmid and M.T. Murphy
Publisher: Prentice-Hall
Number of users responding to survey: 109
Geographical distribution of respondents: BC (108), YT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	89	12	88	1
The relationship of the text's objectives with your own priorities	89	16	84	3
Readability for students	88	19	81	5
Illustrations, photographs, etc.	87	14	86	2
Suggested activities	86	16	84	3
Canadian examples	85	25	75	7
Accounts of the applications of science	87	29	71	8
Appropriateness for slow students	87	70	30	10
Appropriateness for bright students	86	20	80	6
References for further reading	82	52	48	9
Overall impression	86	12	88	

Title: *Earth Science*
Author(s): W.L. Ramsey *et al.*
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 10
Geographical distribution of respondents: Nfld. (6), Sask. (4)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	9	11	89	1
The relationship of the text's objectives with your own priorities	9	22	78	2
Readability for students	9	22	78	2
Illustrations, photographs, etc.	9	33	67	4
Suggested activities	9	33	67	4
Canadian examples	10	60	40	9
Accounts of the applications of science	9	67	33	10
Appropriateness for slow students	10	50	50	6
Appropriateness for bright students	8	50	50	6
References for further reading	9	56	44	8
Overall impression	8	37	63	

Title: *Les êtres et leur milieu*
Author(s): M. Poirier and G. Viscasillas
Publisher: Brault et Bouthillier
Number of users responding to survey: 10
Geographical distribution of respondents: NB (2), Qué. (6), Man. (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	10	50	50	5
The relationship of the text's objectives with your own priorities	10	40	60	3
Readability for students	10	60	40	8
Illustrations, photographs, etc.	10	10	90	1
Suggested activities	10	50	50	5
Canadian examples	10	40	60	3
Accounts of the applications of science	10	50	50	5
Appropriateness for slow students	10	100	0	10
Appropriateness for bright students	10	20	80	2
References for further reading	10	70	30	9
Overall impression	10	40	60	

Title: *Exploring Matter and Energy*
Author(s): Milo K. Blecha *et al.*
Publisher: Doubleday
Number of users responding to survey: 35
Geographical distribution of respondents: Nfld. (1), NS (1), NB (17), Sask. (1), Alta. (7), BC (8)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	26	42	58	6
The relationship of the text's objectives with your own priorities	26	46	54	8
Readability for students	25	16	84	1
Illustrations, photographs, etc.	25	24	76	3
Suggested activities	25	20	80	2
Canadian examples	23	30	70	4
Accounts of the applications of science	24	37	63	5
Appropriateness for slow students	24	42	58	6
Appropriateness for bright students	24	62	38	10
References for further reading	24	50	50	9
Overall impression	24	33	67	

Title: *Exploring Science Series*
Author(s): W.A. Thurber and R.E. Kilburn
Publisher: Macmillan of Canada Ltd.
Number of users responding to survey: 75
Geographical distribution of respondents: Nfld. (20), PEI (15), NS (28), Man. (7), Alta. (1), BC (3), YT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	62	48	52	3
The relationship of the text's objectives with your own priorities	61	59	41	6
Readability for students	63	62	38	7
Illustrations, photographs, etc.	63	40	60	1
Suggested activities	63	52	48	3
Canadian examples	63	84	16	10
Accounts of the applications of science	63	63	37	8
Appropriateness for slow students	63	81	19	9
Appropriateness for bright students	63	40	60	1
References for further reading	62	55	45	5
Overall impression	63	65	35	

Comment: In two cases (f and h), the number of "completely inadequate" responses exceeded the number of responses in other categories.

Title: *Extending Science Concepts in the Laboratory*
Author(s): M. Schmid *et al.*
Publisher: Prentice-Hall
Number of users responding to survey: 98
Geographical distribution of respondents: BC (97), YT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	87	32	68	1
The relationship of the text's objectives with your own priorities	86	51	49	4
Readability for students	85	73	27	7
Illustrations, photographs, etc.	86	70	30	6
Suggested activities	85	53	47	5
Canadian examples	85	79	21	8
Accounts of the applications of science	85	85	15	9
Appropriateness for slow students	85	89	11	10
Appropriateness for bright students	85	40	60	2
References for further reading	83	48	52	3
Overall impression	85	65	35	

Title: *Focus on Life Science*
Author(s): C.H. Heimler and J.D. Lockard
Publisher: Charles E. Merrill
Number of users responding to survey: 15
Geographical distribution of respondents: Ont. (1), Man. (7), Sask. (7)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	8	12	88	2
The relationship of the text's objectives with your own priorities	8	12	88	2
Readability for students	8	25	75	5
Illustrations, photographs, etc.	8	0	100	1
Suggested activities	8	25	75	5
Canadian examples	8	62	38	9
Accounts of the applications of science	8	25	75	5
Appropriateness for slow students	8	75	25	10
Appropriateness for bright students	8	12	88	2
References for further reading	8	25	75	5
Overall impression	8	25	75	

Title: *Initiation aux sciences physiques*
Author(s): U. Haber-Schaim *et al.*, translated and adapted by J.M. Chevrier
Publisher: Institut de recherches psychologiques
Number of users responding to survey: 12
Geographical distribution of respondents: Qué. (11), Man. (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	12	33	67	5
The relationship of the text's objectives with your own priorities	12	25	75	2
Readability for students	12	50	50	6
Illustrations, photographs, etc.	12	25	75	2
Suggested activities	12	25	75	2
Canadian examples	12	92	8	8
Accounts of the applications of science	12	67	33	7
Appropriateness for slow students	12	92	8	8
Appropriateness for bright students	12	17	83	1
References for further reading	12	100	0	10
Overall impression	12	17	83	

Title: *Introducing Science Concepts in the Laboratory*
Author(s): M.C. Schmid and M.T. Murphy
Publisher: Prentice-Hall
Number of users responding to survey: 91
Geographical distribution of respondents: BC (90), YT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	72	6	94	1
The relationship of the text's objectives with your own priorities	71	21	79	3
Readability for students	72	26	74	4
Illustrations, photographs, etc.	72	37	63	6
Suggested activities	71	20	80	2
Canadian examples	71	44	56	7
Accounts of the applications of science	71	70	30	9
Appropriateness for slow students	72	76	24	10
Appropriateness for bright students	72	33	67	5
References for further reading	71	62	38	8
Overall impression	72	14	86	

Title: *Introduction à la biologie: perspective écologique*
Author(s): P. Thibault and R. D'Aoust
Publisher: Editions Hurtubise HMH
Number of users responding to survey: 15
Geographical distribution of respondents: NB (3), Qué. (12)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	15	40	60	4
The relationship of the text's objectives with your own priorities	15	40	60	4
Readability for students	15	40	60	4
Illustrations, photographs, etc.	15	27	73	2
Suggested activities	15	60	40	8
Canadian examples	15	33	67	3
Accounts of the applications of science	14	57	43	7
Appropriateness for slow students	15	73	27	9
Appropriateness for bright students	15	20	80	1
References for further reading	14	79	21	10
Overall impression	15	47	53	

Title: *Life Science, A Problem Solving Approach*
Author(s): Joseph L. Carter *et al.*
Publisher: Ginn
Number of users responding to survey: 10
Geographical distribution of respondents: Sask. (1), Alta. (7), NWT (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	9	11	89	1
The relationship of the text's objectives with your own priorities	9	22	78	2
Readability for students	9	33	67	5
Illustrations, photographs, etc.	9	22	78	2
Suggested activities	9	22	78	2
Canadian examples	8	38	62	6
Accounts of the applications of science	9	78	22	8
Appropriateness for slow students	9	89	11	10
Appropriateness for bright students	9	44	56	7
References for further reading	8	88	12	9
Overall impression	9	11	89	

Title: *Methods of Science Today, Physical Science 3-4*
Author(s): George Erwin *et al.*
Publisher: Clarke, Irwin
Number of users responding to survey: 34
Geographical distribution of respondents: Ont. (33), NWT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	30	37	63	4
The relationship of the text's objectives with your own priorities	30	50	50	5
Readability for students	30	33	67	2
Illustrations, photographs, etc.	30	27	73	1
Suggested activities	29	34	66	3
Canadian examples	28	54	46	7
Accounts of the applications of science	29	52	48	6
Appropriateness for slow students	31	68	32	9
Appropriateness for bright students	28	61	39	8
References for further reading	29	76	24	10
Overall impression	28	46	54	

Title: *Physical Science: A Problem Solving Approach*
Author(s): Joseph L. Carter *et al.*
Publisher: Ginn
Number of users responding to survey: 10
Geographical distribution of respondents: Ont. (2), Alta. (7), NWT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	9	33	67	3
The relationship of the text's objectives with your own priorities	9	44	56	6
Readability for students	9	33	67	3
Illustrations, photographs, etc.	9	33	67	3
Suggested activities	9	22	78	1
Canadian examples	9	67	33	9
Accounts of the applications of science	9	22	78	1
Appropriateness for slow students	9	67	33	9
Appropriateness for bright students	9	44	56	6
References for further reading	9	44	56	6
Overall impression	9	33	67	

Title: *Physical Science: An Introductory Study*
Author(s): William Andrews *et al.*
Publisher: Prentice-Hall
Number of users responding to survey: 87
Geographical distribution of respondents: PEI (5), Ont. (32), Man. (2), Sask. (37), Alta. (11)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	77	13	87	2
The relationship of the text's objectives with your own priorities	76	18	82	4
Readability for students	76	17	83	3
Illustrations, photographs, etc.	76	18	82	4
Suggested activities	76	11	89	1
Canadian examples	71	52	48	8
Accounts of the applications of science	76	51	49	7
Appropriateness for slow students	76	75	25	9
Appropriateness for bright students	76	25	75	6
References for further reading	75	75	25	9
Overall impression	76	16	84	

Title: *Scienceways*
Author(s): John MacBean *et al.*
Publisher: Copp Clark Pitman
Number of users responding to survey: 46
Geographical distribution of respondents: NS (2), NB (43), NWT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	31	29	71	4
The relationship of the text's objectives with your own priorities	32	37	63	5
Readability for students	32	37	63	5
Illustrations, photographs, etc.	32	19	81	1
Suggested activities	32	22	78	2
Canadian examples	32	41	59	7
Accounts of the applications of science	29	41	59	7
Appropriateness for slow students	32	56	44	10
Appropriateness for bright students	32	22	78	2
References for further reading	28	46	54	9
Overall impression	31	35	65	

Comment: This series is made up of two books, "Green Level" and "Blue Level."

Title: *Searching for Structure*
Author(s): D.H. Pike (General Editor)
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 93
Geographical distribution of respondents: Nfld (84), PEI (1), NS (8)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	80	14	86	1
The relationship of the text's objectives with your own priorities	80	15	85	2
Readability for students	80	29	71	6
Illustrations, photographs, etc.	80	18	82	3
Suggested activities	80	24	76	5
Canadian examples	78	32	68	7
Accounts of the applications of science	77	39	61	9
Appropriateness for slow students	79	58	42	10
Appropriateness for bright students	79	23	77	4
References for further reading	78	36	64	8
Overall impression	79	15	85	

Title: *Biological Science: An Ecological Approach* (BSCS Green)
Author(s): Biological Sciences Curriculum Study
Publisher: Rand McNally
Number of users responding to survey: 57
Geographical distribution of respondents: NS (3), Ont. (1), Sask. (16), Alta. (2), BC (34), YT (1).

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	50	32	68	3
The relationship of the text's objectives with your own priorities	48	33	67	4
Readability for students	48	21	79	1
Illustrations, photographs, etc.	47	23	77	2
Suggested activities	48	50	50	7
Canadian examples	47	94	6	10
Accounts of the applications of science	47	64	36	8
Appropriateness for slow students	49	65	35	9
Appropriateness for bright students	48	48	52	6
References for further reading	46	41	59	5
Overall impression	47	34	66	

Title: *Biological Science: An Inquiry Into Life* (BSCS Yellow)
Author(s): Biological Sciences Curriculum Study
Publisher: Harcourt, Brace, Jovanovich, Inc./Longman
Number of users responding to survey: 8
Geographical distribution of respondents: NS (1), Ont. (5), Man. (1), Alta. (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	7	14	86	3
The relationship of the text's objectives with your own priorities	7	14	86	3
Readability for students	7	14	86	3
Illustrations, photographs, etc.	7	0	100	1
Suggested activities	7	43	57	6
Canadian examples	7	86	14	10
Accounts of the applications of science	7	71	29	8
Appropriateness for slow students	7	71	29	8
Appropriateness for bright students	7	0	100	1
References for further reading	7	43	57	6
Overall impression	7	14	86	

Title: *Biological Science: Molecules To Man* (BSCS Blue)
Author(s): Biological Science Curriculum Study
Publisher: Houghton Mifflin
Number of users responding to survey: 12
Geographical distribution of respondents: Qué. (1), Man. (11)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	11	9	91	2
The relationship of the text's objectives with your own priorities	11	9	91	2
Readability for students	11	9	91	2
Illustrations, photographs, etc.	11	9	91	2
Suggested activities	11	36	64	8
Canadian examples	11	82	18	9
Accounts of the applications of science	11	27	73	6
Appropriateness for slow students	11	82	18	9
Appropriateness for bright students	11	0	100	1
References for further reading	11	27	73	6
Overall impression	11	9	91	

Title: *Biology*
Author(s): John W. Kimball *et al.*
Publisher: Addison-Wesley
Number of users responding to survey: 20
Geographical distribution of respondents: Ont. (10), Alta. (10)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	15	7	93	2
The relationship of the text's objectives with your own priorities	15	13	87	4
Readability for students	15	33	67	6
Illustrations, photographs, etc.	15	7	93	2
Suggested activities	14	71	29	8
Canadian examples	13	85	15	9
Accounts of the applications of science	15	53	47	7
Appropriateness for slow students	15	93	7	10
Appropriateness for bright students	15	0	100	1
References for further reading	15	27	73	5
Overall impression	15	20	80	

Title: *Biology: Living Systems*
Author(s): R.F. Oram *et al.*
Publisher: Charles E. Merrill
Number of users responding to survey: 36
Geographical distribution of respondents: Nfld. (35), Ont. (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	28	7	93	1
The relationship of the text's objectives with your own priorities	28	7	93	1
Readability for students	28	29	71	7
Illustrations, photographs, etc.	28	11	89	3
Suggested activities	28	25	75	6
Canadian examples	28	86	14	9
Accounts of the applications of science	28	54	46	8
Appropriateness for slow students	28	86	14	9
Appropriateness for bright students	28	14	86	4
References for further reading	27	15	85	5
Overall impression	28	11	89	

Title: *Foundations of Biology*
Author(s): W.D. McElroy *et al.*
Publisher: Prentice-Hall Canada
Number of users responding to survey: 34
Geographical distribution of respondents: NB (8), Alta. (1), BC (22), YT (2), NWT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	28	39	61	2
The relationship of the text's objectives with your own priorities	28	46	54	5
Readability for students	28	46	54	5
Illustrations, photographs, etc.	28	39	61	2
Suggested activities	27	78	22	8
Canadian examples	27	93	7	9
Accounts of the applications of science	28	57	43	7
Appropriateness for slow students	28	93	7	9
Appropriateness for bright students	28	25	75	1
References for further reading	28	43	57	4
Overall impression	28	54	46	

Title: *Modern Biology*
Author(s): J.H. Otto *et al.*
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 70
Geographical distribution of respondents: NS (28), Ont. (4), Sask. (19), Alta. (16), NWT (3)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	63	8	92	1
The relationship of the text's objectives with your own priorities	63	22	78	3
Readability for students	63	19	81	2
Illustrations, photographs, etc.	64	25	75	4
Suggested activities	64	61	39	8
Canadian examples	63	86	14	10
Accounts of the applications of science	63	57	43	7
Appropriateness for slow students	63	68	32	9
Appropriateness for bright students	63	33	67	6
References for further reading	63	29	71	5
Overall impression	63	22	78	

Title: *Understanding Living Things*
Author(s): J. Reimer and W. Wilson
Publisher: D.C. Heath
Number of users responding to survey: 6
Geographical distribution of respondents: NS (2), Ont. (4)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	5	80	20	7
The relationship of the text's objectives with your own priorities	5	80	20	7
Readability for students	5	60	40	3
Illustrations, photographs, etc.	5	80	20	7
Suggested activities	5	60	40	3
Canadian examples	4	25	75	1
Accounts of the applications of science	5	40	60	2
Appropriateness for slow students	5	80	20	7
Appropriateness for bright students	5	60	40	3
References for further reading	4	75	25	6
Overall impression	5	80	20	

Title: *ALCHEM*
Author(s): Frank Jenkins *et al.*
Publisher: J.M. LeBel
Number of users responding to survey: 14
Geographical distribution of respondents: Alta. (13), BC (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	14	21	79	2
The relationship of the text's objectives with your own priorities	14	21	79	2
Readability for students	14	7	93	1
Illustrations, photographs, etc.	14	43	57	9
Suggested activities	14	36	64	8
Canadian examples	14	7	93	1
Accounts of the applications of science	14	21	79	2
Appropriateness for slow students	14	50	50	10
Appropriateness for bright students	14	29	71	6
References for further reading	14	29	71	6
Overall impression	14	29	71	

Title: *Chemistry: An Experimental Science*
Author(s): G. Pimentel *et al.*
Publisher: W.H. Freeman
Number of users responding to survey: 8
Geographical distribution of respondents: Qué. (1), Man. (1), Sask. (6)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	7	29	71	1
The relationship of the text's objectives with your own priorities	7	29	71	1
Readability for students	8	75	25	10
Illustrations, photographs, etc.	7	43	67	3
Suggested activities	7	43	67	3
Canadian examples	7	71	29	8
Accounts of the applications of science	6	50	50	6
Appropriateness for slow students	7	71	29	8
Appropriateness for bright students	6	33	67	3
References for further reading	6	67	33	7
Overall impression	6	33	67	

Title: *Chemistry: Experimental Foundations*
Author(s): Robert W. Parry *et al.*
Publisher: Prentice-Hall Canada
Number of users responding to survey: 23
Geographical distribution of respondents: Qué. (1), Ont. (7), Man. (3), Sask. (10), Alta. (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	20	0	100	1
The relationship of the text's objectives with your own priorities	20	15	85	3
Readability for students	20	35	65	5
Illustrations, photographs, etc.	20	20	80	4
Suggested activities	20	40	60	6
Canadian examples	20	95	5	10
Accounts of the applications of science	20	80	20	8
Appropriateness for slow students	20	90	10	9
Appropriateness for bright students	20	10	90	2
References for further reading	20	65	35	7
Overall impression	20	15	85	

Title: *Chemistry: Experiments and Principles*
Author(s): Paul R. O'Connor *et al.*
Publisher: D.C. Heath
Number of users responding to survey: 26
Geographical distribution of respondents: Nfld. (7), NS (1), Qué. (3), Ont. (2), Man. (3), Alta. (10)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	22	18	82	3
The relationship of the text's objectives with your own priorities	22	18	82	3
Readability for students	22	14	86	2
Illustrations, photographs, etc.	22	18	82	3
Suggested activities	22	36	64	6
Canadian examples	22	91	9	9
Accounts of the applications of science	22	54	46	7
Appropriateness for slow students	22	95	5	10
Appropriateness for bright students	22	9	91	1
References for further reading	22	82	18	8
Overall impression	22	18	82	

Title: *Chemistry Today*
Author(s): R.L. Whitman and E.E. Zinck
Publisher: Prentice-Hall
Number of users responding to survey: 30
Geographical distribution of respondents: NS (13), Qué. (3), Ont. (14)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	23	17	83	1
The relationship of the text's objectives with your own priorities	23	17	83	1
Readability for students	23	17	83	1
Illustrations, photographs, etc.	23	35	65	4
Suggested activities	23	56	44	8
Canadian examples	23	48	52	6
Accounts of the applications of science	23	48	52	6
Appropriateness for slow students	23	65	35	10
Appropriateness for bright students	23	43	57	5
References for further reading	23	61	39	9
Overall impression	23	17	83	

Title: *La chimie: expériences et principes*
Author(s): Paul R. O'Connor *et al.*, translated by J. Leclerc
Publisher: Centre Éducatif et Culturel
Number of users responding to survey: 7
Geographical distribution of respondents: Qué. (7)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	7	57	43	5
The relationship of the text's objectives with your own priorities	7	43	57	3
Readability for students	7	57	43	5
Illustrations, photographs, etc.	7	29	71	2
Suggested activities	7	43	57	3
Canadian examples	7	86	14	9
Accounts of the applications of science	7	71	29	7
Appropriateness for slow students	7	100	0	10
Appropriateness for bright students	7	0	100	1
References for further reading	7	71	29	7
Overall impression	7	57	43	

Title: *Éléments de chimie expérimentale*
Author(s): R. Lahaie *et al.*
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 15
Geographical distribution of respondents: Qué. (14), Ont. (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	15	27	73	1
The relationship of the text's objectives with your own priorities	15	47	53	5
Readability for students	15	40	60	2
Illustrations, photographs, etc.	15	40	60	2
Suggested activities	15	60	40	7
Canadian examples	15	47	53	5
Accounts of the applications of science	15	60	40	7
Appropriateness for slow students	15	73	27	9
Appropriateness for bright students	15	27	73	1
References for further reading	15	87	13	10
Overall impression	15	47	53	

Title: *Foundations of Chemistry*
Author(s): E.R. Toon and G.L. Ellis
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 30
Geographical distribution of respondents: Ont. (11), Man. (2), BC (15), YT (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	22	5	95	1
The relationship of the text's objectives with your own priorities	22	9	91	4
Readability for students	22	5	95	1
Illustrations, photographs, etc.	22	23	77	6
Suggested activities	22	23	77	6
Canadian examples	22	73	27	9
Accounts of the applications of science	22	14	86	5
Appropriateness for slow students	21	86	14	10
Appropriateness for bright students	22	5	95	1
References for further reading	22	27	73	8
Overall impression	22	5	95	

Title: *Inquiries in Chemistry*
Author(s): A.M. Turner and C.T. Sears, Jr.
Publisher: Allyn & Bacon
Number of users responding to survey: 40
Geographical distribution of respondents: NS (1), NB (11), BC (28)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	38	18	82	2
The relationship of the text's objectives with your own priorities	38	45	55	6
Readability for students	37	16	84	1
Illustrations, photographs, etc.	37	32	68	3
Suggested activities	37	57	43	7
Canadian examples	35	77	23	10
Accounts of the applications of science	35	71	29	8
Appropriateness for slow students	36	72	28	9
Appropriateness for bright students	37	38	62	5
References for further reading	35	37	63	4
Overall impression	37	32	78	

Title: *Interaction of Matter and Energy*
Author(s): N. Abraham *et al.*
Publisher: Rand McNally
Number of users responding to survey: 8
Geographical distribution of respondents: NB (1), Sask. (5), BC (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	7	0	100	1
The relationship of the text's objectives with your own priorities	7	29	71	6
Readability for students	7	14	86	5
Illustrations, photographs, etc.	7	0	100	1
Suggested activities	7	0	100	1
Canadian examples	7	100	0	10
Accounts of the applications of science	7	71	29	8
Appropriateness for slow students	7	71	29	8
Appropriateness for bright students	7	0	100	1
References for further reading	7	43	57	7
Overall impression	7	14	86	

Title: *Keys to Chemistry*
Author(s): Elaine Ledbetter and Jay Young
Publisher: Addison-Wesley
Number of users responding to survey: 14
Geographical distribution of respondents: Ont. (2), Man. (2), Alta. (4), BC (4), YT (1), NWT (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	13	31	69	5
The relationship of the text's objectives with your own priorities	13	23	77	3
Readability for students	13	8	92	1
Illustrations, photographs, etc.	13	31	69	5
Suggested activities	13	46	54	7
Canadian examples	13	69	31	10
Accounts of the applications of science	13	46	54	7
Appropriateness for slow students	13	62	38	9
Appropriateness for bright students	12	17	83	2
References for further reading	13	23	77	3
Overall impression	13	38	62	

Title: *Modern Chemistry*
Author(s): J. Metcalfe *et al.*
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 21
Geographical distribution of respondents: PEI (8), NS (4), NB (1), Sask. (7), Alta. (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	16	19	81	1
The relationship of the text's objectives with your own priorities	16	31	69	3
Readability for students	16	44	56	4
Illustrations, photographs, etc.	16	50	50	5
Suggested activities	16	56	44	6
Canadian examples	16	87	13	9
Accounts of the applications of science	16	62	38	7
Appropriateness for slow students	16	87	13	9
Appropriateness for bright students	16	19	81	1
References for further reading	16	62	38	7
Overall impression	16	31	69	

Title: *Fundamentals of Physics*
Author(s): R.W. Heath *et al.*
Publisher: D.C. Heath
Number of users responding to survey: 53
Geographical distribution of respondents: NS (3), Qué. (1), Ont. (17), Sask. (13), BC (19)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	45	7	93	4
The relationship of the text's objectives with your own priorities	45	4	96	3
Readability for students	45	2	98	1
Illustrations, photographs, etc.	45	2	98	1
Suggested activities	45	18	82	5
Canadian examples	42	26	74	6
Accounts of the applications of science	43	28	72	7
Appropriateness for slow students	43	40	60	9
Appropriateness for bright students	44	29	71	8
References for further reading	42	74	26	10
Overall impression	45	7	93	

Title: *Matter and Energy*
Author(s): J.H. MacLachlan *et al.*
Publisher: Clarke, Irwin
Number of users responding to survey: 26
Geographical distribution of respondents: Ont. (26)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	15	7	93	1
The relationship of the text's objectives with your own priorities	15	13	87	2
Readability for students	15	20	80	4
Illustrations, photographs, etc.	15	40	60	5
Suggested activities	15	73	27	9
Canadian examples	15	47	53	6
Accounts of the applications of science	15	60	40	7
Appropriateness for slow students	15	87	13	10
Appropriateness for bright students	15	13	87	2
References for further reading	15	67	33	8
Overall impression	15	33	67	

Title: *Physics (PSSC)*
Author(s): U. Haber-Schaim *et al.*
Publisher: D.C. Heath
Number of users responding to survey: 48
Geographical distribution of respondents: NS (1), Qué. (6), Ont. (18), Man. (10), Sask. (6), BC (6)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	41	10	90	2
The relationship of the text's objectives with your own priorities	41	20	80	3
Readability for students	41	59	41	7
Illustrations, photographs, etc.	41	20	80	3
Suggested activities	41	41	59	6
Canadian examples	41	98	2	10
Accounts of the applications of science	41	73	27	8
Appropriateness for slow students	41	93	7	9
Appropriateness for bright students	41	5	95	1
References for further reading	41	32	68	5
Overall impression	41	22	78	

Title: *Physics: A Human Endeavour*
Author(s): D. Paul *et al.*
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 36
Geographical distribution of respondents: Nfld. (15), NS (4), NB (8), Ont. (1), Alta. (8)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	33	18	82	1
The relationship of the text's objectives with your own priorities	33	30	70	3
Readability for students	33	18	82	1
Illustrations, photographs, etc.	33	33	67	4
Suggested activities	33	33	67	4
Canadian examples	33	48	52	8
Accounts of the applications of science	33	42	58	6
Appropriateness for slow students	33	67	33	10
Appropriateness for bright students	33	42	58	6
References for further reading	33	61	39	9
Overall impression	33	33	67	

Title: *Physique (PSSC)*
Author(s): U. Haber-Schaim *et al.*, translated and adapted by P. Tougas
Publisher: Centre Éducatif et Culturel
Number of users responding to survey: 8
Geographical distribution of respondents: Qué. (6), Ont. (1), Man. (1)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	6	33	67	4
The relationship of the text's objectives with your own priorities	6	17	83	3
Readability for students	6	67	33	7
Illustrations, photographs, etc.	6	0	100	1
Suggested activities	6	50	50	5
Canadian examples	6	83	17	9
Accounts of the applications of science	6	67	33	7
Appropriateness for slow students	6	100	0	10
Appropriateness for bright students	6	0	100	1
References for further reading	6	50	50	5
Overall impression	6	17	83	

Title: *Project Physics*
Author(s): J. Rutherford *et al.*
Publisher: Holt, Rinehart & Winston
Number of users responding to survey: 8
Geographical distribution of respondents: Alta. (6), NWT (2)

Feature	N	I	II	R
		%	%	
Appropriateness of the science content for the grade level you teach	6	17	83	1
The relationship of the text's objectives with your own priorities	6	50	50	6
Readability for students	6	17	83	1
Illustrations, photographs, etc.	6	17	83	1
Suggested activities	6	33	67	5
Canadian examples	6	67	33	8
Accounts of the applications of science	6	50	50	6
Appropriateness for slow students	6	83	17	10
Appropriateness for bright students	6	17	83	1
References for further reading	6	67	33	8
Overall impression	6	33	67	

Appendix D – Analytical Schemes Used in Textbook Analysis

A slightly revised version of the document provided for the analysts appears below. It was accompanied by a response sheet on which the information was collected in a standard format.

1. Stated Intentions of Science Textbooks
2. Canadian Context in Science Textbooks
3. Science-Technology-Society Interactions in Science Textbooks
4. Nature of Science (and the History of Science and Technology)
5. Careers
6. Scientific Skills/Processes

Analysis Scheme No. 1

Stated Intentions of Science Textbooks

The purpose of this part of the textbook analysis is to identify and classify the intentions stated by the authors of textbooks. These are normally to be found in the preface, but it is often necessary to look elsewhere. You will, therefore, have to study the first chapter of the textbook, which sometimes contains answers to the question: "Why study science?," a list of learning goals (if one exists), the table of contents and, indeed, any part of the book likely to contain an explicit message from the authors regarding the goals of science teaching that they wish students to attain. You should also examine the teacher's manual.

It should be noted that the absence of a stated goal is no guarantee that the author does not provide opportunities to attain one. However, here we are only interested in those types of intentions that the authors consider sufficiently important to state explicitly.

Once you have identified the stated intentions, they should be classified according to the following eight categories:

1. Science Content
2. Scientific Skills/Processes
3. Science and Society
4. Nature of Science (including the history of science and technology)
5. Personal Growth
6. Science-Related Attitudes
7. Applied Science/Technology
8. Career Opportunities

A number of criteria follow, together with examples that will facilitate the classification.

1. Science Content: Include here all goals that are directly related to learning the facts, laws and theories that make up what is commonly called "science content." For example:

> "Its main purpose is to provide you with knowledge about the physical world."[1]
>
> "There are two major aims in studying biology. One aim is to become acquainted with scientific facts and with ideas that are built on them."[2]

It is worth noting that the method of expressing an intention varies from author to author. The intentions may involve the book, the teacher, or the student and are not always phrased in such a way as to identify observable behaviour. Sometimes they are simply phrased as statements.

2. Scientific Skills/Processes: Include here goals connected with the intellectual processes promoted by the author as a way of acquiring scientific knowledge. This would include the scientific method, investigation, aptitudes such as creativity, hypothesizing, experimental verification and so on. For example:

> "To acquaint you with the scientific method of inquiry."[3]
>
> "It is hoped that during this course you will develop a more inquiring attitude, and that you will think more clearly. Perhaps you will be able to communicate more positively than to say 'well, like, it sort of went green.' "[4]

3. Science and Society: The goals to be listed here include those that mention explicitly the social impact of science and technology. We mean by "social impact," changes affecting the individual and the community in such areas as health, work, communications, lifestyle, the economy, politics and the total environment. For example:

> "The basic aim of this unit is to enable students to understand energy sufficiently for them to make wise decisions about the use of energy in the future and the conservation of energy in the present."[5]
>
> "We have therefore taken the trouble to give examples [. . .] which illustrate the social implications, be they good or bad, of scientific progress."[6]

4. Nature of Science (including the history of science and technology): List here: a) those goals in which the authors express their point of view on what science is; b) the authors' goals regarding the history of science and technology. For example:

> "To help students see physics as the wonderfully many-sided human activity that it really is. This means presenting the subject in historical and cultural perspective."[7]

"We will see the nature of science by engaging in scientific activity. We will see the nature of chemistry by considering problems which interest chemists."[8]

5. Personal Growth: List here intentions related to the student's general development (cognitive, psychomotor and affective). It is often difficult to identify them and they are not always present. For example:

"This particular science book is designed to give you the opportunity to think clearly and act responsibly in dealing with your environment and your life."[9]

"So children are encouraged to respect the knowledge and opinions of others — scientists and writers, teachers and parents, and also other children."[10]

6. Science-Related Attitudes: List here the authors' intentions regarding the attitudes that students should acquire towards science: enthusiasm, respect, caution, curiosity, interest and so on. For example:

"To develop students' attitudes of curiosity, of wonderment about and involvement with phenomena in their natural environment; to develop an appreciation for the contributions of science to daily living; and to develop the value and inclination towards solving problems in a scientific manner."[11]

7. Applied Science and Technology: List here the intentions expressed by the authors regarding a knowledge of technology and of applications of science. If these intentions include social considerations, they should be entered under category 3. For example:

"Time should also be spent discussing the chemical industry and organic reactions."[12]

8. Career Opportunities: List here the intentions expressed by the authors concerning careers in science and technology. For example:

"To make students aware that many careers are directly related to science and that a knowledge of science is helpful in people's work and in their daily life."[13]

Analysis Scheme No. 2

Canadian Context in Science Textbooks

The goal of this part of the study is to measure the extent to which a Canadian context is present in science textbooks. The initial problem facing us is the definition of what we understand by "Canadian context." As we pointed out in the rationale for the study, the scientific *content* of a textbook represents the sum total of the scientific facts, laws and theories. The *context* is defined as the sum total of all the information that does not form part of the content. The Canadian context is, therefore, that part of the general context that makes reference to Canada in each of the following aspects: physical, historical and sociocultural.

The term "Canadian context" raises the question of nationalism in science teaching. We have no desire to enter into the debate over the universality and unity of science, nor to discuss what constitutes an acceptable quantity of Canadian context. These questions have already been the subject of extended debate and continue to generate heated discussion. Our aim here is to furnish data for these debates and discussions. For the purposes of this analysis, we will use the following definition of the Canadian context in science textbooks: *The body of the information contained in the textbook that is unequivocally related to Canadian circumstances in all forms, and to whatever is unique therein.*

Our preliminary research has revealed that the Canadian context, when it is present, takes a wide variety of forms and cannot be entirely determined from the table of contents or from the index. In that it is generally very unevenly distributed, it is impossible to give a rigorously valid account through an analysis of a random sample of chapters or pages. This analysis must, therefore, consider each page in detail.

The analytical scheme is composed of a series of questions, the answers to which will enable us to:

- determine the degree to which a Canadian context is present;
- quantify passages in which the Canadian context is replaced by a foreign context for no compelling reason.

The degree to which a Canadian context is present will be determined using three dimensions of the context: physical, historical and sociocultural.

1. Physical Dimension: This dimension is composed of all the messages that include a reference to the Canadian geographic environment. These may be illustrations (photographs, drawings or graphics) or phrases such as:

> "In California, for example, is magnetic north east or west of true North? In Québec, on which side of true north is magnetic north? In Florida? In Newfoundland?"[14]

2. Historical Dimension: This dimension involves all the messages concerning the history of scientific or technological activity in Canada. Below are some examples:

> "In 1879, an outstanding Canadian engineer, Sir Sandford Fleming, suggested dividing the earth into time zones."[15]
>
> "The first reactor in operation outside of the U.S. is the ZEE (Zero Energy Experimental Pile) which started up on September 5, 1945 at Chalk River, Ontario."[16]

3. Sociocultural Dimension: The analyst should compile all those messages that bear on the impact of scientific and technological activity on the economic, political, social and cultural aspects of Canadian life. One example:

> "More and more Canadians are buying processed foods because they are easier to prepare. However, processing food can remove vitamins from it. In Canada, we add some vitamins to many processed foods to replace those that are lost during the processing. This is called enriching the foods."[17]

The Foreign Context

In 1973, the Ontario Royal Commission on publishing in Canada concluded as follows:

> "Let it be clear that we would never advocate the artificial incorporation of the Canadian content where this would be irrelevant to the purpose of a book. What we do call for is the presentation of subject matter from a Canadian perspective whenever the alternative is a foreign perspective."[18]

To what extent do science textbooks continue to give preference to a foreign perspective in Canadian schools? In order to answer this question, we must examine those aspects of the context which present a *non-Canadian* point of view when a Canadian point of view would have been more appropriate and possible. Below is an example:

> "And if we wait, what should be done about the serious power shortage that now exists in the Northeastern United States, and that threatens to become a problem for the entire nation?"[19]

Analysis Scheme No. 3

Science-Technology-Society Interactions in Science Textbooks

Most of the ministries and departments of education in Canada believe that one of the aims of the teaching of science is to make students aware of the social implications of science and technology. The following two examples illustrate this.

Aims of the teaching of natural sciences (Québec, elementary level):

> "To enable the child to develop as an independent, creative individual who is called upon to live in a scientific and technological society."[20]

Goals of the chemistry program (Nova Scotia, senior-high level):

> "Students will acquire the basic chemical knowledge in making decisions required of *participating citizens of a technological nation.* They will develop a realistic as opposed to a hostile or fearful attitude to chemistry.
>
> "This will be accomplished through an understanding of the influences of chemistry and chemical technology on our society, our everyday life and our environment. By becoming aware of the potential uses and abuses of chemical knowledge, students will

question the uses to which chemistry and chemical technology are put."[21]

This tendency to give a social perspective to the teaching of science is not unique to Canada. Glen Aikenhead remarks that "the need for a science and engineering teaching program that takes their interactions with society into account. . . has been spotlighted in Canada, Australia, Great Britain and the United States, and at the international level by UNESCO."[22]

This part of the analysis of textbooks is aimed at determining whether the science textbooks used in Canada contain information or pedagogical strategies designed to present scientific and technological activity in a social light.

Identification of STS Interactions in a Textbook

A preliminary study has enabled us to discern two ways in which the social impacts of science and technology are incorporated in science textbooks:

- by structuring the contents of books on the basis of these impacts and using them as a justification for the teaching of science;
- by mentioning the social consequences of science and technology in passing, for example, by examining the questions raised by nuclear power generation during the study of nuclear reactions in chemistry or physics.

Some authors, for many reasons, do not include any social considerations in their textbooks. Regardless of how the authors may choose to incorporate a social context, we shall define STS interaction in a textbook as follows: *The sum total of messages containing information on the social impact of scientific and technological activity and the sum total of the pedagogical strategies (questions, experiments, projects, etc.) designed to make the student aware of this impact.*

Taking as a basis the works of Glen Aikenhead,[23] John Ziman,[24] and Graham Orpwood and Douglas Roberts,[25] we shall classify these messages according to four categories that, in our view, constitute what is essential for STS interaction for the primary and secondary levels.

1. Messages that invite students to use their scientific and technological knowledge for applications of benefit to themselves or their community;
2. Messages that describe the beneficial or detrimental effects of scientific and technological activity on the welfare of society, at the national and international levels;
3. Messages dealing with the ways in which a society exploits scientific and technological knowledge to solve national or international problems;

4. Messages dealing with the ethical and legal aspects of scientific and technological activity.

Here are several examples of messages taken from a sampling of textbooks and classified according to the four categories.

Category 1:

"City and community planning is one kind of conservation. Have a member of a government planning commission visit your class to explain how community planning aids the conservation of human resources."[26]

"Make up a menu for one day of foods that you like. It should be worth 38 points. You must show it supplies the right amount of energy, carbohydrates, fats, proteins, vitamins, minerals, fibre and water."[27]

Category 2:

"What about labour-saving household appliances? Do they really make life easier for the upper- and middle-income families who own them? 'Not much,' says the critic, because the work done by such machines was previously done by servants anyway. Of course industrialization and electrification have created some jobs for people with little training. These jobs may be more attractive than work as a servant, but they still do not pay very well. As a result, many low-income families cannot afford more than one major electrical appliance. The one usually purchased by such families is a television set, which, the skeptics say, is not likely to contribute much to improving the quality of life."[28]

Category 3:

"Humanity faces the problem of overpopulation. Scientists are trying to find new means of solving the problem of overpopulation. They are looking for ways of: producing more food; controlling harmful organisms and diseases; developing new agricultural regions; designing houses to accommodate greater number of individuals."[29]

Category 4:

"The use and control of nuclear weapons is a vital issue in the world today. Scientists taking part in the development of the bomb were foremost among those insisting that further bomb testing be halted. The result was a moratorium on atmospheric nuclear testing by several countries in 1963."[30]

Finally, the following criteria are added:

- The passages must be topical in character. Any account of STS interaction in the past will be included in the same analysis of the history of science in science textbooks; and
- mere descriptions of the application of science, e.g. "one or more of the hydrogen atoms of ethylene can be replaced by groups such as -F, -C1, $-CH_3$ or $-COOCH_3$. The resulting products are synthetic polymers with such commercial names as Teflon, Saran, Lucite and Plexiglass"[31] will not be taken as messages about STS interaction. The description of the social impact here, for all practical purposes, is nonexistent.

The analyst must identify messages relevant to STS interaction, classify them according to their categories and, on the basis of a line count, measure the percentage of space they occupy within the chapters from which they have been taken. For each category the analyst must seek the following information.

Category 1: This includes

- the kind of activity called for (personal or collective action and in what environment – home, school, community);
- the nature of this activity (direct action, information gathering or reflection);
- the frequency of these activities.

Indicate the number of activities in the following table:

Category 1: Table

	Direct action	Information gathering	Reflection
School			
Home			
Community			

Number of activities suggesting personal action____________________

Number of activities suggesting collective action____________________

Each analyst should select one or two messages they believe to be representative and copy them out.

Category 2: This includes

- the kind of scientific and technological activity that has consequences for society;
- the beneficial or detrimental nature of these consequences, according to the author;
- the presence of a discussion on the beneficial or detrimental nature of these consequences;

- the location of these consequences (national or international point of view).

Enter these items in the following table:

Category 2: Table

Type of consequence	Consequence considered beneficial/ detrimental	Discussion present yes/no	Location national international	% in the chapter (estimate)
1.				
2.				
3.				
4.				
etc.				

Category 3: This includes

- nature of the problems for which science and technology can provide a solution;
- degree of certainty, according to the author, with which this solution can be found;
- context of the problem (national or international).

Enter these items in the following table:

Category 3: Table

Nature of the problem and description of the solution	Degree of certainty absolute/ doubtful	Context national/ international	% in the chapter (estimate)
1.			
2.			
3.			
4.			
etc.			

Category 4: This includes

- problems in which ethical considerations are evoked; nature of these problems and context;
- problems in which legal considerations are evoked (regulation, etc.); and nature of these problems and context.

Enter these items in the following table:

Category 4: Table

Problems	Character ethical/legal	Context national international	% in the chapter (estimate)
1.			
2.			
3.			
4.			
etc.			

Analysis Scheme No. 4

Nature of Science (and the History of Science and Technology)

The ways in which the authors of textbooks present the nature of science and the history of scientific and technological activity, as well as the space they devote to the history of the sciences vary considerably. The reasons why the authors of textbooks introduce a certain historical depth into their works are also very different. At all events, passages relating to the history of the sciences and the nature of scientific activity, when present, are the subject of critical comment.

> "A preliminary analysis of the image of the scientist (the genius) and his role in the evolution of scientific knowledge, shows that only a partial picture of the reality is conveyed, one that tends to perpetuate myths. Now, all pedagogical activity of this kind contributes to the student's alienation. He will assume that these scientific 'whizzes' are responsible for the growth of knowledge and will believe that this field is reserved for an élite, in short he will be in awe of the persons and statements of these scientific geniuses.'"[32]

> "Significant discrepancies exist between the historical record of science and historical content often included in science textbooks. The consequences of distorted historical content are particularly significant for that majority of students who do not become scientists."[33]

Thomas Russell, the author of the second quotation, commented that "there is an. . . important need for research which studies *the provision actually made by textbooks and by teaching* for students to develop images of science and scientists."[34] This part of the analysis is in part a response to this recommendation. Its aim, in fact, will be to examine the kinds of steps the authors take to inform students about the history of science and the nature of its activities.

Specifically, the analysis must answer the following two questions:

- To what extent is the history of science presented in the textbook and in what form?
- What concept of the nature of science do the authors advance?

1. History of science

Aims: Copy out the authors' intentions (if stated) regarding the inclusion of historical aspects in their textbooks. (Refer to scheme #1)

Scientists (in the text): Using the index, copy down the names of all the scientists mentioned and the page numbers of the textbooks on which the authors discuss them; then answer the following questions.

- What is the total number of scientists mentioned?
- Of these, how many are mentioned only to characterize a law or theory? (For example: "We can therefore write $P_1V_1 = P_2V_2$. This is called Boyle's law." "In 1887, *Heinrich Herz* discovered a phenomenon called the photoelectric effect.")
- Of the total number, how many of the accomplishments of scientists are described in a manner conforming to a traditional concept of the scientific method (observations, hypotheses, experiments, etc.)?
- Of the total number of scientists counted above, how many are described in an historical and social context?
- Of the total number of scientists, how many are mentioned in connection with a research group or an exchange of information between them and their colleagues?
- Classify the scientists by nationality and determine the percentage for each country.
- What percentage of the scientists are women?

Case Studies: A case study in the history of science, according to Klopfer and Watson:

> "involves the critical study of the development of a major scientific concept. [It] not only involves the final result of the scientific inquiry but stresses the scientists who were involved, the information available to them, their search for better facts and explanations, and the intellectual and social climate in which they worked."[35]

The analysis must answer the following questions:

- Does the textbook include case studies in the history of science that involve all the elements pointed out by Klopfer and Watson? Look for a study *critical* in nature about the development of a major scientific concept that mentions the scientists involved and their relationship, the information available to them, *how* they searched for better facts and explanations and the intellectual and social climate in which they worked.
- If so, how many?

- And on what subjects? Select up to three case studies that show a high degree of breadth and quality.
- The "great men" approach and the "case studies" approach have been selected because they most frequently occur in science textbooks. Does the textbook examined present any particular approach to the history of science that seems original? What seems to be conveyed by this approach? Please illustrate.
- Does the textbook reproduce original illustrations or publications associated with the history of science? If yes, how many?

2. The nature of science
- Copy out the definitions of science (or of a particular discipline: physics, biology, etc.) given by the authors.
- Copy out the descriptions of the scientific method (or scientific approach, scientific thought processes, investigation, etc.) given by the authors.
- Illustrate types of information relevant to the nature of science, i.e., material from which students might reasonably be able to deduce, "Science is like this. . . "
- Estimate the quantity of each of such statements *on average* through the book based on random samples of text.

Analysis Scheme No. 5

Careers

To what extent do the textbooks deal with careers in the fields of science and engineering and invite students to consider these fields? This part of the analysis is intended to provide answers to these two questions. Bear in mind that the analysis is descriptive in its intent. The question of determining whether it is appropriate to invite pre-university students to consider scientific careers, like the question of determining whether science textbooks are the most suitable vehicles for conveying such suggestions, will be discussed at a later time.

The analyst must answer the following questions:
- Does the textbook contain anything about careers in science and engineering?
- If yes, make a list of the careers described in the textbooks.
- For each career answer the following questions: What level of education is required for this career? Pre-university, Bachelor's degree, Master's degree, or Doctoral degree? Is it of a multidisciplinary character? Do the authors mention the names of potential employers? Do the authors indicate the personal skills needed for this type of career? If the career in question is illustrated by photographs, how many of them are of men? of women? Is the student explicitly invited to adopt this career?

Analysis Scheme No. 6

Scientific Skills/Processes

Laboratory work provides students with various occasions to develop particular scientific skills and processes through direct interaction with materials. The laboratory manual is the part of the textbook concerned with these activities and contains instructions to be followed by the student in order to carry out experiments. The instructions translate into specific tasks that will be examined in this analysis by using an instrument (the "Laboratory Structure and Task Analysis Inventory") designed by Marlene Fuhrman, Vincent Lunetta, Shimshon Novick and Pinchas Tamir. Since the complete instrument with instructions for its use has been published elsewhere, only the basic categories are reproduced below.

The goal of this part of the analysis consists of sorting out the types of laboratory activities suggested by textbook writers and identifying the types of intended behavioural outcomes of these activities. At a later stage, we will assess the degree of commonality between the scientific skills/processes expected by ministries of education and those intended to be developed through the use of the laboratory workbooks.

Laboratory Structure and Task Analysis Inventory

Organizational Categories

A. Structure
- a.1 High structure
- a.2 Low structure, open
- a.3 Inductive approach
- a.4 Deductive approach

B. Relation to Text
- b.1 Precedes text
- b.2 Follows text
- b.3 Integrated with text

C. Cooperative Mode
- c.1 Students work on a common task and pool results
- c.2 Students work on different tasks and pool results
- c.3 Postlab discussion required

D. Laboratory Simulations
- d.1 Student performs "dry lab" — data given by authors
- d.2 Student performs task that simulates or models phenomena
- d.3 Student performs experiment by gathering data from a secondary source

d.4 Student performs simulated experiment by interacting with a program

Task Categories

1.0 Planning and Design
- 1.1 Formulates a question or defines problem to be investigated
- 1.2 Predicts experimental result
- 1.3 Formulates hypothesis to be tested in this investigation
- 1.4 Designs observation or measurement procedure
- 1.5 Designs experiment

2.0 Performance
- 2.1a Carries out qualitative observation
- 2.1b Carries out quantitative observation or measurement
- 2.2 Manipulates apparatus; develops technique
- 2.3 Records results, describes observation
- 2.4 Performs numeric calculation
- 2.5 Interprets, explains or makes a decision about experimental technique
- 2.6 Works according to own design

3.0 Analysis and Interpretation
- 3.1a Transforms results into standard form (other than graphs)
- 3.1b Graphs data
- 3.2a Determines qualitative relationship
- 3.2b Determines quantitative relationship
- 3.3 Determines accuracy of experimental data
- 3.4 Defines or discusses limitations and/or assumptions that underlie the experiment
- 3.5 Formulates or proposes a generalization or model
- 3.6 Explains a relationship
- 3.7 Formulates new questions or defines problem based upon results of investigation

4.0 Application
- 4.1 Makes predictions based upon results of this investigation
- 4.2 Formulates hypothesis based upon results of this investigation
- 4.3 Applies experimental technique to new problem or variable

Notes

I. Focus of the Study

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

2. *Ibid.*, p. 142.

3. David Suzuki, " 'Science' Should Start with an R," *Maclean's*, 21 January 1980, p. 4.

4. For example, David Suzuki, "The Impact of Science and Technology on Education," Address at the annual convention of the Canadian Education Association, Vancouver, 24 September 1980.

5. Translated from, Jacques Désautels, *École + Science = Échec*, Québec Science Éditeur, Québec, 1980, p. 11.

6. See, for example, National Science Foundation and Department of Education, *Science and Engineering Education for the 1980s and Beyond*, Report to the President, Washington, D.C., 1980.

7. For example, Association for Science Education, *Education Through Science*, Policy Statement, Hatfield, Herts., 1981.

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9. For an analysis of the intellectual moves involved, see Martin Rein and Donald A. Schön, "Problem Setting in Policy Research," in *Using Social Research in Public Policy Making*, edited by Carol H. Weiss, Lexington Books, Lexington, Mass., 1977, pp. 235-251.

10. Douglas A. Roberts, "Developing the Concept of 'Curriculum Emphases' in Science Education," *Science Education*, 1982, vol. 60, no. 2, pp. 243-260.

11. Chris Argyris and Donald A. Schön, *Theory in Practice: Increasing Professional Effectiveness*, Jossey-Bass Publishers, San Francisco, 1974.

12. Douglas A. Roberts, *op. cit.*, p. 245.

13. Douglas A. Roberts, "Curriculum Emphases as a Key Area for Decision Making: The Case of School Science," in *Studies of Curriculum Decision Making*, ed. K.A. Leithwood, OISE Press, Toronto, 1982.

14. Douglas A. Roberts and Graham W.F. Orpwood, *Properties of Matter: A Teacher's Guide to Alternative Versions*, OISE Press, Toronto, 1979.

15. Douglas A. Roberts and Graham W.F. Orpwood, "Classroom Events and Curricular Intentions: A Case Study in Science Education," *Canadian Journal of Education*, 1982, vol. 7, no. 2, pp. 1-15.

16. Chris Argyris and Donald A. Schön, *op. cit.*, p. 4.

17. Chris Argyris, *Reasoning, Learning, and Action: Individual and Organizational*, Jossey-Bass Publishers, San Francisco, 1982, p. 83.

18. Chris Argyris and Donald A. Schön, *op. cit.*, p. 7.

19. Chris Argyris, *op. cit.*, p. 85.

II. Deliberative Inquiry

1. Much of this section is based directly on Graham W.F. Orpwood, "The Logic of Curriculum Policy Deliberation: An Analytic Study from Science Education," Unpublished doctoral dissertation, University of Toronto, 1981. (ED 211 372)

2. Cf. Leroi B. Daniels, "The Concept of Curriculum," Paper presented at the annual meeting of the Canadian Society for the Study of Education, Halifax, 1981.

3. For example, K.A. Leithwood *et al.*, *Planning Curriculum Change*, OISE Press, Toronto, 1976; see especially chapter 4.

4. Len Berk, Editorial, *Curriculum Inquiry*, 1976, vol. 6, no. 2, pp. 99-100.

5. *Ibid.*, p. 100.

6. This distinction is taken from Ernest R. House, "Technology versus Craft: A Ten Year Perspective on Innovation," *Journal of Curriculum Studies*, 1979, vol. 11, no. 1, p. 11.

7. Aristotle, *The Politics*, VIII, 2, 1337a(33) — 1337b(1).

8. F. Michael Connelly, Florence G. Irvine and Robin J. Enns, "Stakeholders in Curriculum," in *Curriculum Planning for the Classroom*, edited by F.M. Connelly, A.S. Dukacz and F. Quinlan, OISE Press, Toronto, 1980, pp. 44-55.

9. *Ibid.*, p. 44.

10. The deliberative method for attending to curriculum problems is described by Joseph J. Schwab, *The Practical: A Language for Curriculum*, National Education Association, Washington, D.C., 1970, and "The Practical 3: Translation into Curriculum," *School Review*, August 1973, vol. 81, no. 4, pp. 501-522.

11. Graham W.F. Orpwood, "The Ethics of Involvement by Researchers in Curriculum Policymaking," *Journal of Educational Thought*, December 1983, vol. 17, no. 3, pp. 221-229; also William A. Reid, "Schools, Teachers, and Curriculum Change: The Moral Dimension of Theory Building," *Educational Theory*, Fall 1979, vol. 29, no. 4.

12. Other papers in the series are: Glen Aikenhead, *Science in Social Issues: Implications for Teaching*; Donald George, *An Engineer's View of Science Education*; Hugh Munby, *What is Scientific Thinking?*; Marcel Risi, *Macroscole: A Holistic Approach to Science Teaching*; Douglas Roberts, *Scientific Literacy: Towards Balance in Setting Goals for School Science Programs.*

13. Workshop proceedings published to date are as follows: *Who Turns the Wheel?*, Proceedings of a workshop on the science education of women, edited by Janet Ferguson; *Québec Science Education: Which Directions?*, edited by Jean-Pascal Souque and Paul Dufour.

14. Joseph J. Schwab, *The Practical: A Language for Curriculum*, National Education Association, Washington, D.C., 1970, p. 36.

III. Research for Policy Deliberation

1. Stephen Toulmin, *Human Understanding*, Princeton University Press, Princeton, N.J., p. 153.

2. See, for example, several essays in A. Hugh Munby, Graham W.F. Orpwood and Thomas L. Russell, *Seeing Curriculum in a New Light: Essays from Science Education*, OISE Press, Toronto, 1980; also Donald A. Schön, *The Reflective Practitioner: How Professionals Think in Action*, Basic Books, New York, 1983.

3. Freema Elbaz, "The Teacher's Practical Knowledge: A Case Study," Unpublished doctoral dissertation, University of Toronto, 1980.

4. Geoffrey Vickers, *The Art of Judgment: A Study of Policymaking*, Chapman and Hall, London, 1965, p. 39.

5. Robert E. Stake and Jack A. Easley, Jr., *Case Studies in Science Education*, US Government Printing Office, Washington, D.C., 1978.

6. John Olson and Thomas Russell, "Draft Plans for a Series of Case Studies of Canadian Science Education," Unpublished paper prepared for the Science and Education Committee of the Science Council of Canada, October 1980, p. 3.

7. Sam D. Seiber, "The Integration of Fieldwork and Survey Methods," *American Journal of Sociology*, 1973, vol. 78, no. 6, pp. 1335-1359.

IV. Science in the School Curriculum

1. In English, the term "ministry" is actually used only in Ontario and British Columbia; elsewhere in Canada, "department" is the designation for the branch of the provincial or territorial government responsible for education. In this study, however, we use "ministry" as the generic term and "department" or "ministry" (as appropriate) when referring to specific jurisdictions. In French, the term "ministère" is universally applicable.

2. Part of the agreement between the Science Council of Canada and CMEC was that an undertaking by the Science Council would not duplicate studies already conducted by CMEC. The work described in the following CMEC reports has, therefore, not been verified by us: *Secondary Education in Canada: A Student Transfer Guide*, 3rd edition, Council of Ministers of Education, Canada, Toronto, 1981; *Science: A Survey of Provincial Curricula at the Elementary and Secondary Levels*, prepared by Sharon M. Haggerty and E.D. Hobbs for the Curriculum Committee of the Council of Ministers of Education, Canada, Toronto, 1981.

3. "Science," for the purposes of this study, is that subject area so designated by each province or territory (see chapter I for further discussion on this point).

4. In this area, the work of Paul Dufour, research associate at the Science Council, is gratefully acknowledged.

5. The three levels (early, middle and senior) are defined in chapter I.

6. See Graham W.F. Orpwood, "The Logic of Curriculum Policy Deliberation: An Analytic Study from Science Education," Unpublished doctoral dissertation, University of Toronto, 1981, especially chapter 3.

7. For example, Secretary of State, *English Educational Publishing in Canada* and *French Educational Publishing in Canada*, Supply and Services Canada, Ottawa, 1978.

V. The Official Aims and Strategies of Science Education

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2. *Ibid.*, p. 9.

3. For example, the eight "dimensions of scientific literacy" of Lawrence L. Gabel, "The Development of a Model to Determine Perceptions of Scientific Literacy," Unpublished doctoral dissertation, Ohio State University, Columbus, Ohio, 1976; also the seven "curriculum emphases" identified by Douglas A. Roberts, "Developing the Concept of 'Curriculum Emphases' in Science Education," *Science Education*, 1982, vol. 60, no. 2, pp. 243-260.

4. Certainly the first two and possibly higher levels also of Bloom's taxonomy of cognitive objectives fall within this category. See Benjamin S. Bloom,

Taxonomy of Educational Objectives: The Classification of Educational Goals, Hardbook 1: Cognitive Domain, David McKay, New York, 1956.

5. Cf. Roberts's "correct explanations" and "solid foundation" emphases (Douglas A. Roberts, "Developing the Concept of 'Curriculum Emphases' in Science Education," *Science Education,* 1982, vol. 60, no. 2, pp. 247-249).

6. For a discussion of the objectives of this program see, for example, Robert M. Gagné, "Elementary Science: A New Scheme of Instruction," *Science,* 1966, no. 151, pp. 49-53. Canadian research in the area of process skills in science education includes Marshall Nay, "A Process Approach to Teaching Science," *Science Education,* 1971, vol. 55, no. 2, pp. 197-207.

7. A. Hugh Munby, *What is Scientific Thinking?,* Discussion paper, Science Council of Canada, Ottawa, 1982.

8. Exceptions include materials published by the SEEDS Foundation (Edmonton) and by OISE Press (Toronto).

9. For example, Graham W.F. Orpwood and Douglas A. Roberts, "Science and Society: Dimensions of Science Education for the 80s," *Orbit,* February 1980, no. 51; also Glen Aikenhead, *Science in Social Issues: Implications for Teaching,* Science Council of Canada, Ottawa, 1981.

10. Newfoundland Department of Education, *Elementary Science Course Description,* St. John's, Newfoundland, January 1978, p. 3.

11. See A. Hugh Munby, "An Evaluation of Instruments Which Measure Attitudes to Science," in *World Trends in Science Education,* edited by C.P. MacFadden, Atlantic Institute of Education, Halifax, 1980.

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13. Frank W. Jenkins *et al., ALCHEM,* J.M. LeBel, Edmonton, 1979.

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15. Haggerty and Hobbs, *op. cit.,* p. 3.

16. This point is argued in detail in Douglas A. Roberts and Graham W.F. Orpwood, "Classroom Events and Curricular Intentions: A Case Study in Science Education," *Canadian Journal of Education,* 1982, vol. 7, no. 2, pp. 1-15.

17. Marcel Risi, *Macroscole: A Holistic Approach to Science Teaching,* Science Council of Canada, Ottawa, 1982.

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VI. Textbooks in Science Education

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2. Québec, Ministry of Education, *The Schools of Québec, Policy Statement and Plan of Action,* Québec City, 1979, p. 103.

3. Saskatchewan Education, *Science: A Curriculum Guide for Division III,* Regina, 1979, p. 9.

4. Doris W. Ryan, *Ontario Classroom Textbook Survey,* The School Group of the Canadian Book Publishers' Council in cooperation with the Ontario Teachers' Federation, Toronto, 1982, p. 67.

VII. Descriptive Analysis: Aims and Methodology

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2. Paul R. O'Connor *et al., Chemistry: Experiments and Principles,* D.C. Heath, Toronto, 1982, p. vii.
3. R.W. Heath and R. R. MacNaughton, *Physical Science: Interaction of Matter and Energy,* D.C. Heath, Toronto, 1976, p. 197.
4. Thomas F. Morrison *et al., Précis de biologie humaine,* translated by André Décarie, Éditions HRW, Montréal, 1977, p. 4 (our translation).
5. *Ibid.,* p. 188, (our translation).
6. O'Connor *et al., op. cit.,* p. 330.
7. Graham W.F. Orpwood, "Canadian Content in School Texts and Changing Goals of Education," *Education Canada,* Spring 1980, vol. 20, no. 1, p. 19.
8. Thomas Russell, "What History of Science, How Much, and Why?" *Science Education,* 1981, vol. 65, no. 1, p. 56.
9. Marlene Fuhrman *et al., The Laboratory Structure and Task Analysis Inventory - LAI: A User's Handbook,* Technical Report 14, University of Iowa Science Education Center, Iowa City, 1978.

VIII. Descriptive Analysis: Results

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3. School Group, Canadian Book Publishers' Council, *Textbooks are for Everyone,* Toronto, n.d.
4. U. Haber-Schaim *et al., PSSC Physics,* 5th edition, D.C. Heath, Toronto, 1981, p. 128.
5. Marlene Fuhrman *et al., op. cit.*
6. Vincent N. Lunetta and Pinchas Tamir, "Matching Lab Activities with Teaching Goals," *The Science Teacher,* 1979, vol. 46, no. 3, pp. 22-24.
7. Pinchas Tamir and Vincent N. Lunetta, "Inquiry-related Tasks in High School Science Laboratory Handbooks," *Science Education,* 1981, vol. 65, no. 5, pp. 477-484.
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13. James Page, *A Canadian Context for Science Education,* Science Council of Canada, Ottawa, 1979.
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15. *Ibid.,* p. 460.

16. Biological Sciences Curriculum Study, *Biological Science: An Ecological Approach* (BSCS Green Version), Rand McNally, Chicago, 1978, pp. 46-53.
17. *Ibid.*, pp. 194-195.
18. J.W. Kimball, *Biology*, Addison-Wesley, Toronto, 1978.
19. J.J. Otto and Albert Towle, *Modern Biology*, Holt, Rinehart & Winston, Toronto, 1969, p. 610.
20. *Ibid.*, p. 140.
21. Robert W. Parry *et al.*, *Chemistry: Experimental Foundations*, Prentice-Hall, Scarborough, 1975, pp. 228-229.
22. *Ibid.*, p. 493.
23. Paul O'Connor *et al.*, *Chemistry: Experiments and Principles*, D.C. Heath, Toronto, 1977, p. 95.
24. Paul R. O'Connor *et al.*, *La Chimie: Expériences et principes*, version française par Jacques Leclerc, Centre Éducatif et Culturel, Montréal, 1974, p. 80 (our translation).
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37. René Lahaie *et al.*, *Éléments de chimie expérimentale*, Éditions HRW, Montréal, 1976, p. 7 (our translation).
38. See, for example, Gaston Bachelard, *La Formation de l'esprit scientifique*, J. Vrin, Paris, 1967; also Jean-Pascal Souque and Jacques Désautels, "La course d'obstacles du savoir," *Québec Science*, 1979, vol. 18, no. 1, pp. 36-39.
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