Foundation for the Atlantic Canada Science Curriculum

New Brunswick
Department of Education
Curriculum Development Branch

New Nouveau Brunswick

Science

FOUNDATION

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A Vision for Scientific Literacy

The Atlantic provinces' science curriculum is guided by the vision that all students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge that students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them.

Introduction

PURPOSE OF DOCUMENT

This science curriculum foundation document is intended to be a framework for science programs in the Atlantic provinces. It is meant to reflect current provincial, national, and international thinking on meeting the needs of all students in becoming scientifically literate citizens.

This document outlines the nature of science education, science curriculum outcomes, the instructional philosophy for science, and principles of assessment. It reflects exemplary practices currently taking place in schools and classrooms in Atlantic Canada.

This document has been designed to

- provide teachers with an overview of science education and act as a companion document to curriculum guides
- identify knowledge, skills, and attitudes that nurture the development of scientifically literate individuals
- briefly describe the nature of the instructional environment in which effective science learning can take place
- provide suggestions for the assessment of students' learning specifically related to science
- present the view of the nature of science currently accepted by the majority of the scientific community
- briefly describe the role of science in students' achievement of the Atlantic Canada essential graduation learnings
- serve as the basis for the development of new programs in science, both provincially and for the Atlantic region

CURRICULUM FOCUS

SCIENTIFIC LITERACY

Canadian society is experiencing rapid and fundamental economic, social, and cultural changes that affect the way people live. Canadians are also becoming aware of an increasing global interdependence and the need for a sustainable environment, economy, and society. The emergence of a highly competitive and integrated international economy, rapid technological innovation, and a growing knowledge base will continue to have a profound impact on people's lives. Advancements in science and technology play an increasingly significant role in everyday life. Science education will be a key element in developing scientific literacy and in building a strong future for Canada's young people.

Consistent with views expressed in a variety of national and international science education documents, the following goals for Canadian science education have been established:

- encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours

- enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the lives of others
- prepare students to address critically science-related societal, economic, ethical, and environmental issues
- provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations, and engages them in science-related hobbies appropriate to their interests and abilities
- develop in students, of varying aptitudes and interests, a knowledge of the wide variety of careers related to science, technology, and the environment

The goal of science education in the Atlantic provinces is to develop scientific literacy. The accomplishment of this aim within the school context can take place only if certain opportunities are presented. While teachers play the most significant role in helping students achieve scientific literacy, they need support from the rest of the educational system if the challenge is to be met. Science must be an important component of the curriculum at all grade levels and must be explored in an enjoyable environment that students find interesting and intrinsically rewarding. The designation of science into various categories should be discouraged at the primary and elementary levels. At the high school level students will be introduced to the traditional sciences. These divisions are arbitrary and do not reflect current scientific practice. At all stages of science education the connections within and across the sciences, as well as the connections of science to technology, society and the environment should be stressed.

To achieve scientific literacy for all students (entry–12), the science curriculum is expected to

- address the three basic scientific fields of study—life, physical, and Earth and space science. From entry–9 all students will be exposed to all fields. At the high school level students may opt to take specific sciences. However, in all cases attempts should be made to develop the connections among the basic sciences
- engage students in inquiry, problem solving, and decision-making situations and contexts that give meaning and relevance to the science curriculum. These include the processes of science such as predicting and formulating hypotheses, higher level skills such as critical thinking and evaluating, and manipulative skills such as the use of a microscope and a balance
- utilize a wide variety of print and non-print resources developed in an interesting and interactive style. Common materials, laboratory equipment, audiotapes and videotapes, computer software, and video disks should provide a substantial part of the student's experience
- exhibit the character of science to be open to inquiry and controversy, and free of dogmatism; promote student understanding of how we came to know what we know and how we test and revise our thinking

- give students the opportunities to construct the important ideas of science, which are then developed in depth, through inquiry and investigation
- be presented in connection with students' own experiences and interests by frequently using hands-on experiences that are integral to the instructional sequence
- demonstrate connections across the curriculum
- involve instructional strategies and materials which allow all learners to experience both challenge and success
- incorporate assessment approaches that are aligned philosophically with the instructional program and correlate with the intended program

Student achievement in science and in other school subjects such as social studies, English language arts, and technology is enhanced by coordination between and among the science program and other programs. Furthermore, such coordination can maximize use of time in a crowded school schedule.

THE THREE PROCESSES OF SCIENTIFIC LITERACY

A science education which strives for scientific literacy must engage students in asking and answering meaningful questions. Some of these questions will be posed by the teacher, while others will be generated by the students. These questions are of three basic types: "Why...?" "How...?" and "Should...?". There are three processes used to answer these questions. ***Scientific inquiry*** addresses "why" questions. "How" questions are answered by engaging in the ***problem solving*** process, and "should" questions are answered by engaging in ***decision making.***

Scientific Inquiry

The first of the three processes, scientific inquiry, is a way of learning about the universe. It involves the posing of questions and the search for explanations of phenomena. Although there is no such thing as a "scientific method," students require certain skills to participate in the activity of science. There is general agreement that skills such as questioning, observing, inferring, predicting, measuring, hypothesising, classifying, designing experiments, collecting data, analysing data, and interpreting data are fundamental to engaging in science. These skills are often represented as a cycle which involves the posing of questions, the generation of possible explanations, and the collection of evidence to determine which of these explanations is most useful in accounting for the phenomena under investigation. Teachers should engage students in scientific inquiry activities to develop these skills.

Problem Solving

The second process, problem solving, seeks solutions to human problems. It is also often represented as a cycle. In this case the cycle represents the proposing, creating, and testing of prototypes, products, and techniques in an attempt to reach an optimum solution to a given problem. The skills involved in this cycle, often called the design-technology (DT) cycle, facilitate a process which has different aims and different procedures from the inquiry process. Students should be given ample opportunity in the curriculum to propose, perform, and evaluate solutions to problem-solving or technological tasks or questions.

Decision Making

The third process is decision making. It is the determination of what we, as global citizens, should do in a particular context or in response to a given situation. Increasingly, the types of problems that we deal with, both individually and collectively, require an understanding of the processes and products of science and technology. The actual process of decision making involves the identification of the problem or situation, generation of possible solutions or courses of action, evaluation of the alternatives, and a thoughtful decision based on the information available. Students should be actively involved in decision-making situations as they progress through the science curriculum. Decision-making situations not only are important in their own right, they also often provide a relevant context for engaging in scientific inquiry and/ or problem solving.

Question:	Why does my coffee cool so quickly? (Science question)	How can I make a container to keep my coffee hot? (Technology question)	Should we use styrofoam cups or ceramic mugs for our meeting? (STSE question)
Process Involved in Answering the Question:	Scientific inquiry	Technological problem solving	Decision making
Response:	Heat energy is transferred by conduction, convection, and radiation.	A styrofoam cup will keep liquids warm for a long time.	Personal health, the environment, cost, and availability must be considered along with science and technology information.
Problems Arise from:	Curiosity about events and phenomena in the natural world	Coping with everyday life, practices, and human needs	Different views or perspectives based on different or the same information
Types of Questions:	What do we know? How do we know?	How can we do it? Will it work?	What alternatives or consequences are there? Which choice is best at this time?
Solutions Result in:	Knowledge about the events and phenomena in the natural world	An effective and efficient way to accomplish a task	A defensible decision in the particular circumstances

A COMMON APPROACH

In 1993, work began on the development of common curricula in specific core programs for Atlantic provinces. The Atlantic education ministers' primary purposes for collaborating in curriculum development are to

- improve the quality of education for all students through shared expertise and resources
- ensure that the education students receive across the region is equitable
- meet the needs of both students and society

Under the auspices of the Atlantic Provinces Education Foundation, development of Atlantic common core curricula for mathematics, science, language arts and social studies follows a consistent process. Each project requires consensus by a regional committee at designated decision points; all provinces have equal weight in decision making. Each province has established procedures and mechanisms for communicating and consulting with education partners, and it is the responsibility of the provinces to ensure that stakeholders have input into regional curriculum development.

In February 1995, the Council of Ministers of Education, Canada, adopted the Pan-Canadian Protocol for Collaboration on School Curriculum. *Common Framework of Science Learning Outcomes K–12* was the first joint curriculum development project initiated under the protocol. The framework sets out a vision and foundation statements for scientific literacy in Canada. This vision and the foundation statements are included in the *Foundation for the Atlantic Canada Science Curriculum* document.

The science foundation document includes statements of **essential graduation learnings, general curriculum outcomes** for the program, and **key stage curriculum outcomes** for the end of key stages (entry–grade 2, grades 3–5, grades 6–8, Foundation Years, Graduation Years). Essential graduation learnings and curriculum outcomes provide a consistent vision for the development of a rigorous and relevant core curriculum. In addition to this foundation document, teachers will receive curriculum guides that will include specific curriculum outcomes for the grade levels they teach.

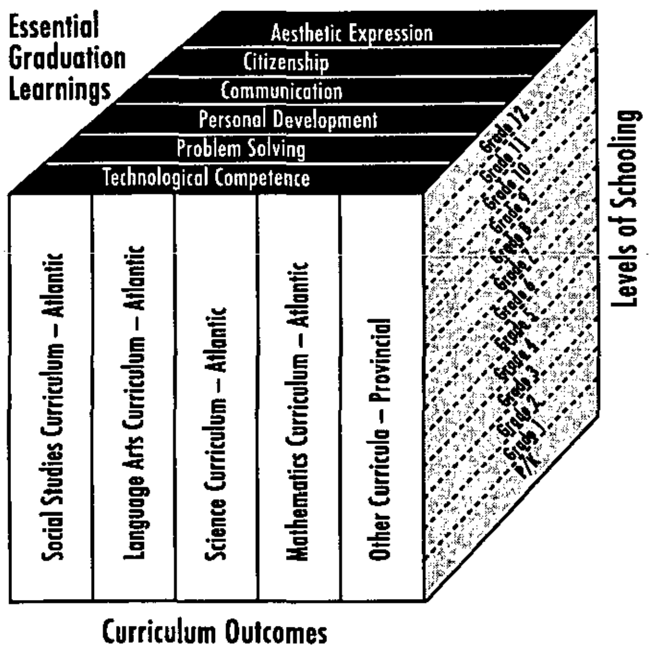
In Atlantic Canada, the general, key-stage, and specific curriculum outcomes for science have been adopted from the Pan-Canadian framework.

Outcomes

Essential graduation learnings *are statements describing the knowledge, skills, and attitudes expected of all students who graduate from high school. Achievement of the essential graduation learnings will prepare students to continue to learn throughout their lives. These learnings describe expectations not in terms of individual school subjects but in terms of knowledge, skills, and attitudes developed throughout the curriculum. They confirm that students need to make connections and develop abilities across subject boundaries if they are to be ready to meet the shifting and ongoing demands of life, work, and study today and in the future. Essential graduation learnings are cross-curricular, and curriculum in all subject areas is focussed to enable students to achieve these learnings. Essential graduation learnings serve as a framework for the curriculum development process.*

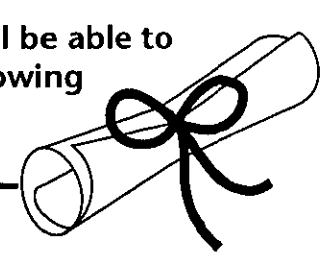
Curriculum outcomes *are statements articulating what students are expected to know and be able to do in particular subject areas. These outcomes statements also describe what knowledge, skills, and attitudes students are expected to demonstrate at the end of certain key stages in their education as a result of their cumulative learning experiences at each grade level in the entry-graduation continuum. Through the achievement of curriculum outcomes, students demonstrate the essential graduation learnings.*

FIGURE 1 – Relationship among Essential Graduation Learnings, Curriculum Outcomes & Levels of Schooling



ESSENTIAL GRADUATION LEARNINGS

Graduates from the public schools of Atlantic Canada will be able to demonstrate knowledge, skills and attitudes in the following essential graduation learnings. Provinces may add additional essential graduation learnings as appropriate.



Aesthetic Expression

Graduates will be able to respond with critical awareness to various forms of the arts and be able to express themselves through the arts.

Graduates will be able to, for example,

- use various art forms as a means of formulating and expressing ideas, perceptions, and feelings
- demonstrate understanding of the contribution of the arts to daily life, cultural identity and diversity, and the economy
- demonstrate understanding of the ideas, perceptions and feelings of others as expressed in various art forms
- demonstrate understanding of the significance of cultural resources such as theatres, museums and galleries

Through an emphasis on the interdependency of living things and on their connections to the physical environment, science fosters the kind of intelligent respect for nature that should inform decisions on the uses of scientific knowledge and technological developments. Without that respect, people are in danger of destroying their life-support systems. Science and technology will be presented in the curriculum as creative human endeavours that must be viewed as comparable to and complementary to other creative endeavours such as the arts and literature.

Citizenship

Graduates will be able to assess social, cultural, economic, and environmental interdependence in a local and global context.

Graduates will be able to, for example,

- demonstrate understanding of sustainable development and its implications for the environment
- demonstrate understanding of Canada's political, social and economic systems in a global context
- explain the significance of the global economy on economic renewal and the development of society
- demonstrate understanding of the social, political and economic forces that have shaped the past and present, and apply those understandings in planning for the future
- examine human rights issues and recognize forms of discrimination
- determine the principles and actions of just, pluralistic and democratic societies
- demonstrate understanding of their own and others' cultural heritage, cultural identity and the contribution of multiculturalism to society

Some of the most serious problems that humans now face are global in nature. Science provides humanity with important knowledge of the biophysical environment and of the behaviours needed to develop effective solutions to global problems. Although many pressing global problems have technological origins, technology may provide the tools for dealing with such problems,

Citizenship (continued)

and the instruments for generating, through science, crucial new knowledge. Without the continuous development and creative use of new technologies, and the continual search for new scientific knowledge, society will limit its capacity for survival and for working toward a world in which the human species is at peace with itself and its environment. The science curriculum will provide numerous examples of interdependence at the local, regional, and global levels.

Scientific and technological habits of mind can help people in every walk of life to deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty. Without the ability to think critically and independently, citizens may fall victim to dogmatism and simplistic solutions to complex issues. In a democratic society it is the citizens who make decisions and who ultimately control science and technology.

The social and economic future of the provinces, the region, and the world depends on the appropriate use of science and technology to manage the resources, to develop new economic opportunities, and to sustain economic vitality, which in turn depends on how well youth are educated to utilize science and technology in decision making and problem solving.

Communication

Graduates will be able to use the listening, viewing, speaking, reading and writing modes of language(s) and mathematical and scientific concepts and symbols, to think, learn and communicate effectively.

Graduates will be able to, for example,

- explore, reflect on, and express their own ideas, learnings, perceptions and feelings
- demonstrate understanding of facts and relationships presented through words, numbers, symbols, graphs and charts
- present information and instructions clearly, logically, concisely and accurately for a variety of audiences
- demonstrate a knowledge of the second official language
- access, process, evaluate and share information
- interpret, evaluate and express data in everyday language
- critically reflect on and interpret ideas presented through a variety of media

Since science is a process for producing knowledge, it is essential that scientists communicate their new-found knowledge in a way that is understandable to the science community and the public at large. Scientific knowledge serves no purpose unless it can be communicated to those to whom it is relevant. The science and technology curriculum will emphasize the importance of, and provide opportunities for, communicating for informing others and for demonstrating an understanding of the scientific concepts and principles.

Personal Development

Graduates will be able to continue to learn and to pursue an active, healthy lifestyle.

Graduates will be able to, for example,

- demonstrate preparedness for the transition to work and further learning
- make appropriate decisions and take responsibility for those decisions
- work and study purposefully both independently and in groups
- demonstrate understanding of the relationship between health and lifestyle
- discriminate among a wide variety of career opportunities
- demonstrate coping, management and interpersonal skills
- demonstrate intellectual curiosity, an entrepreneurial spirit and initiative
- reflect critically on ethical issues

The very nature of science and technology suggests that people depend on each other for knowledge and skills and that cooperative efforts generally produce the quickest and most effective results. While people must understand how scientific knowledge and technological developments affect society, they must, at the same time, understand how they affect them as individuals. Scientific and technological issues are rapidly changing and developing and therefore current information is necessary for a thorough understanding of the issues. The science and technology curriculum will provide opportunities for students to focus and extend their curiosities about the natural world and instil in them a desire for lifelong learning and the refinement of their learning skills.

Problem Solving

Graduates will be able to use the strategies and processes needed to solve a wide variety of problems, including those requiring language, and mathematical and scientific concepts.

Graduates will be able to, for example,

- acquire, process and interpret information critically to make informed decisions
- use a variety of strategies and perspectives with flexibility and creativity for solving problems
- formulate tentative ideas, and question their own assumptions and those of others
- solve problems individually and collaboratively
- identify, describe, formulate and reformulate problems
- frame and test hypotheses
- ask questions, observe relationships, make inferences and draw conclusions
- identify, describe and interpret different points of view and distinguish fact from opinion

Scientists can apply the principles of scientific inquiry to help solve problems in society. These problems are often far too complex for science alone to solve. However, science can play a valuable role by providing factual information, predicting the effects of possible courses of action, and helping to establish relevant causal linkages. Technology is the process and product of human skill and ingenuity in designing creative solutions to human needs and problems. The processes of technology centre around problem solving. Science and technology education will address the needs of students as citizens who need to be critical thinkers, informed decision makers, and creative problem solvers. The curriculum will provide opportunities for students to acquire the skills necessary to live and work in a society that is shaped by science and technology.

Technological Competence

Graduates will be able to use a variety of technologies, demonstrate an understanding of technological applications, and apply appropriate technologies for solving problems.

Graduates will be able to, for example,

- locate, evaluate, adapt, create and share information using a variety of sources and technologies
- demonstrate understanding of and use existing and developing technologies
- demonstrate understanding of the impact of technology on society
- demonstrate understanding of ethical issues related to the use of technology in a local and global context

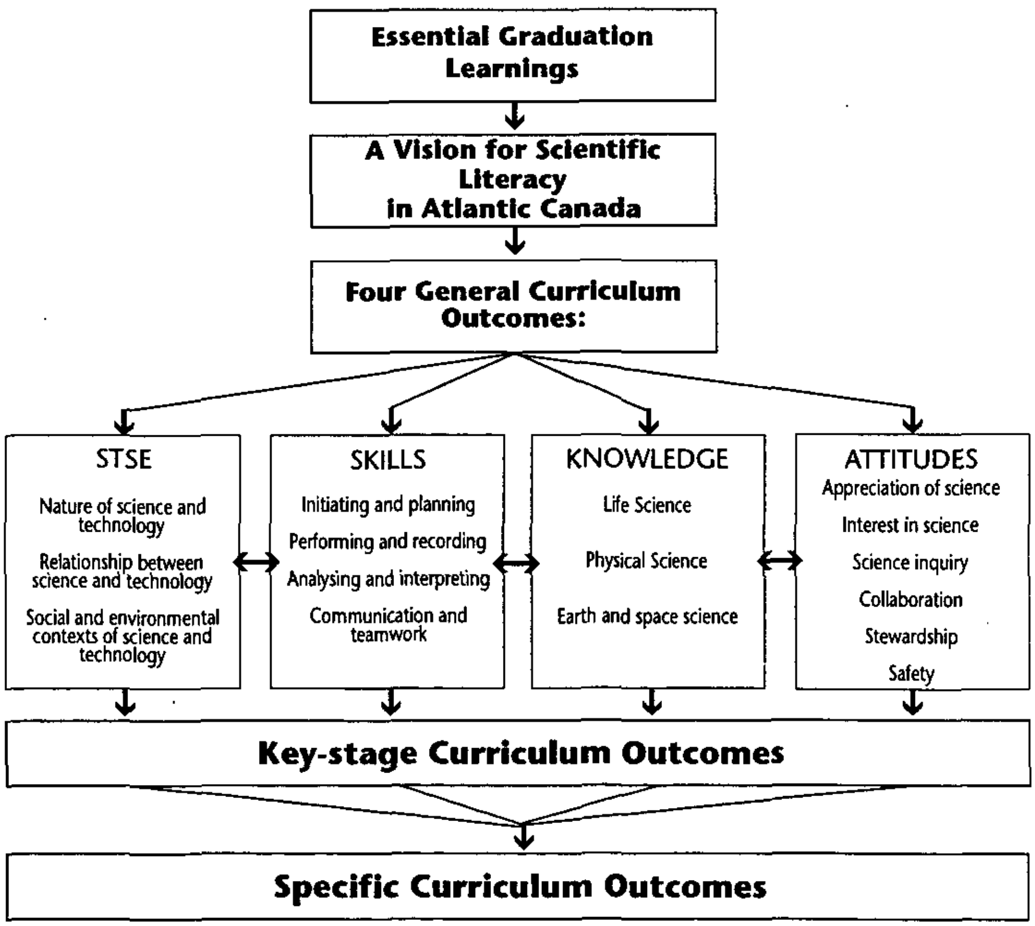
Solving technological problems is the essence of technological competence. In addition to being able to solve technological problems, it is important that students acquire knowledge about technologies and about how technologies affect us individually and collectively. Students should use this knowledge as the basis for using technology effectively. While technological competence through technology integration is the responsibility of the entire curriculum, the science curriculum takes the lead in developing the knowledge, skills, and attitudes essential to students in today's technological society.

A VISION FOR SCIENTIFIC LITERACY

The Atlantic provinces' science curriculum is guided by the vision that all students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge that students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them.

CONCEPTUAL MAP FOR THE OUTCOMES FRAMEWORK

The conceptual map below provides the blueprint of the outcomes framework and is the basis from which general and key-stage outcomes have been developed. At all times when making use of this framework, educators must keep in mind that the outcomes are intended to develop scientific literacy in students. The vision of scientific literacy in this document sets out the need for students to acquire science-related skills, knowledge, and attitudes, and emphasizes that this is best done through the study and analysis of the interrelationships among science, technology, society, and the environment (STSE). The outcomes in the following section are taken from the Pan-Canadian framework document Common *Framework of Science Learning Outcomes K–12.*



GENERAL CURRICULUM OUTCOMES

The general curriculum outcomes form the basis of the outcomes framework. They constitute a starting point for the development of all subsequent work. The also identify the key components of scientific literacy. Four general curriculum outcomes have been identified to delineate the four critical aspects of students' scientific literacy. They reflect the wholeness and interconnectedness of learning and should be considered as interrelated and mutually supportive.

General Curriculum Outcome 1:

Science, technology, society, and the environment (STSE)—*Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.*

General Curriculum Outcome 2:

Skills—*Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.*

General Curriculum Outcome 3:

Knowledge—*Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.*

General Curriculum Outcome 4:

Attitudes—*Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.*

DESCRIPTION OF THE GENERAL CURRICULUM OUTCOMES

The descriptions on the following pages provide an overview of the depth and breadth of each general curriculum outcome, and have been taken from the Pan-Canadian framework document (*Common Framework of Science Learning Outcomes K–12*)

General Curriculum Outcome 1:

Science, technology, society, and the environment (STSE)— *Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.*

This outcome statement is the driving force of the curriculum outcomes framework. Many key-stage curriculum outcomes presented in this document flow directly or indirectly from the STSE domain. The outcome statement focusses on three major dimensions:

- the nature of science and technology
- the relationships between science and technology
- the social and environmental contexts of science and technology

Nature of science and technology

Science is a human and social activity with unique characteristics and a long history that has involved many men and women from many societies. Science is also a way of learning about the universe based on curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over the evidence and its interpretations. Scientific activity provides a conceptual and theoretical base that is used in predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science argue that there is no set procedure for conducting a scientific investigation. Rather, they see science as driven by a combination of theories, knowledge, experimentation, and processes anchored in the physical world. Theories of science are continually being tested, modified, and improved as new knowledge and theories supersede existing ones. Scientific debate on new observations and hypotheses that challenge accepted knowledge involves many participants with diverse backgrounds. This highly complex interplay, which has occurred throughout history, is fuelled by theoretical discussions, experimentation, social, cultural, economic and political influences, personal biases, and the need for peer recognition and acceptance.

While it is true that some of our understanding of the world is the result of revolutionary scientific developments, much of our understanding of the world results from a steady and gradual accumulation of knowledge.

Technology, like science, is a creative human activity with a long history in all cultures of the world. Technology is concerned mainly with proposing solutions to problems arising from human adaptation to the environment. Since there are many possible solutions, there are inevitably many requirements, objectives, and constraints. Hence, the chief concern of technologists is to develop optimal solutions that represent a balance of costs and benefits to society, the economy, and the environment.

Relationships between science and technology

While there are important relationships between science and technology, there are also important differences. Science and technology differ in purpose and in process. Technology is more than applied science. It draws from many disciplines when solving problems. Throughout history, science and technology have drawn from one another. They are inextricably linked.

By understanding the relationships between science and technology, students learn to appreciate how science and technology interact, how they develop in a social context, how they are used to improve people's lives, and how they have implications for the students themselves, for others, for the economy, and for the environment.

Social and environmental contexts of science and technology

The history of science highlights the nature of the scientific enterprise. Above all, the historical context serves as a reminder of the ways in which cultural and intellectual traditions have influenced the questions and methodologies of science, and how science in turn has influenced the wider world of ideas.

Today, a majority of scientists work in industry, where research is more often driven by societal and environmental needs than by the pursuit of fundamentals. As technological solutions have emerged, many of them have given rise to complex social and environmental issues. These issues are increasingly becoming part of the political agenda. The potential of science to inform and empower decision making by individuals, communities, and society as a whole is central to achieving scientific literacy in a democratic society.

Scientific knowledge is necessary but is not in itself sufficient for understanding the relationships among science, technology, society, and the environment. To understand these relationships, it is also essential to understand the values inherent to science, technology, a particular society, and its environment.

As students advance from grade to grade, the understandings about STSE interrelationships are developed and applied in increasingly demanding contexts. In the early years, considerable attention is given to students acquiring an operational understanding of these interrelationships. In the later years, these understandings are more conceptual in nature. Growth in STSE understandings may involve each of the following elements:

- complexity of understanding—from simple, concrete ideas to abstract ideas; from limited knowledge of science to more in-depth and broader knowledge of science and the world
- applications in context—from contexts that are local and personal to those that are societal and global
- consideration of variables and perspectives—from one or two that are simple to many that are complex
- critical judgement—from simple right or wrong assessments to complex evaluations
- decision making—from decisions based on limited knowledge, made with teacher guidance, to decisions based on extensive research, involving personal judgement and made independently, without guidance

General Curriculum Outcome 2:

Skills—*Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.*

Students use a variety of skills in the process of answering questions, solving problems, and making decisions. While these skills are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

The listing of skills is not intended to imply a linear sequence or to identify a single set of skills required in each science investigation. Every investigation and application of science has unique features that determine the particular mix and sequence of skills involved.

Four broad areas of skills are outlined. Each group of skills is developed from entry to grade 12, with increasing scope and complexity of application.

Initiating and planning—These are the skills of questioning, identifying problems, and developing preliminary ideas and plans.

Performing and recording—These are the skills of carrying out a plan of action, which involves gathering evidence by observation and, in most cases, manipulating materials and equipment.

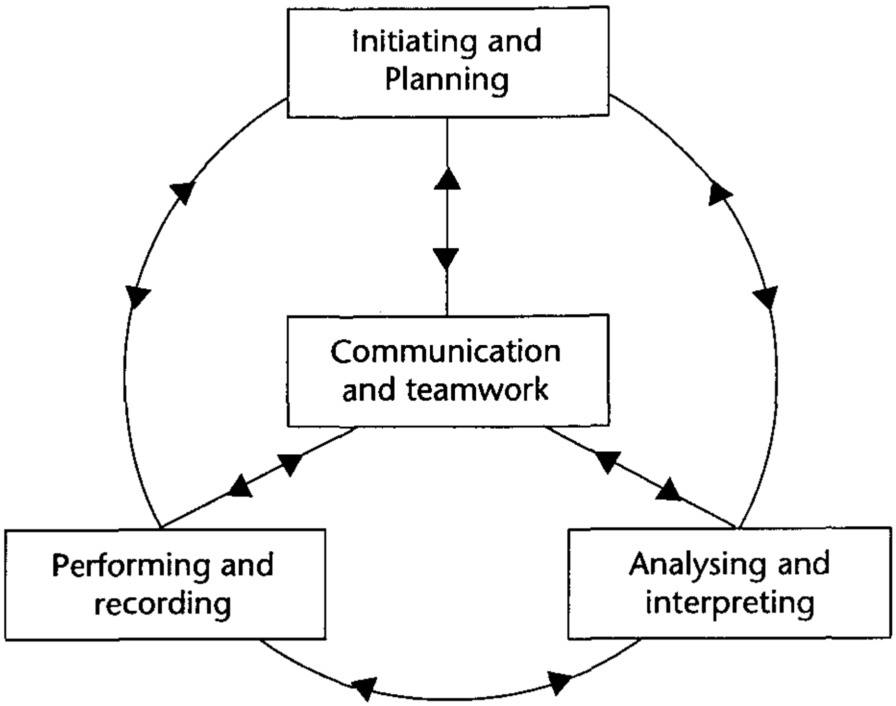
Analysing and interpreting—These are the skills of examining information and evidence, of processing and presenting data so that it can be interpreted, and of interpreting, evaluating, and applying the results.

Communication and teamwork—In science, as in other areas, communication skills are essential at every stage where ideas are being developed, tested, interpreted, debated, and agreed upon. Teamwork skills are also important, since the development and application of science ideas are collaborative processes both in society and in the classroom.

As students advance from grade to grade, the skills they have developed are applied in increasingly demanding contexts. Growth in skills may involve each of the following skill elements:

- range of application—from a limited range to a broad range of applications
- complexity of application—from simple, direct applications to applications that involve abstract ideas and complex interpretations and judgements
- precision of measures and manipulations—from coarse measures and manipulations to those that are precise
- use of current and appropriate technologies and tools—from working with a few simple tools to working with a broad array of specialized and precise tools
- degree of independence and structure—from working under teacher guidance or in a structured situation to working independently and without guidance
- awareness and control—from following a predetermined plan to an approach involving awareness, understanding, and control, such as selecting skills and strategies that are most appropriate to the task at hand and making use of metacognition and strategic thinking
- ability to work collaboratively—from working as an individual to working as part of a team

Interactions among the four areas of skills



Applying skills in context

Students should be provided with opportunities to develop and apply their skills in a variety of contexts. These contexts connect to the STSE outcomes by linking to three processes for skills application:

- science inquiry—seeking answers to questions through experimentation and research
- problem solving—seeking solutions to science-related problems by developing and testing prototypes, products, and techniques to meet a given need
- decision making—providing information to assist the decision-making process

General Curriculum Outcome 3:

Knowledge—*Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.*

This general curriculum outcome focusses on the subject matter of science, including the theories, models, concepts, and principles that are essential to an understanding of each science area. For organizational purposes, this outcome is framed using widely accepted science disciplines.

Life science

Life science deals with the growth and interactions of life forms within their environments, in ways that reflect their uniqueness, diversity, genetic continuity, and changing nature. Life science includes fields of study such as ecosystems, biodiversity, the study of organisms, the study of the cell, biochemistry, genetic engineering, and biotechnology.

Physical science

Physical science, which encompasses chemistry and physics, deals with matter, energy, and forces. Matter has structure and there are interactions among its components. Energy links matter to gravitational, electromagnetic, and nuclear forces in the universe. The conservation laws of mass and energy, momentum, and change are addressed by physical science.

Earth and space science

Earth and space science brings global and universal perspectives to students' knowledge. Earth, our home planet, exhibits form, structure, and patterns of change, as does our surrounding solar system and the physical universe beyond it. Earth and space science includes fields of study such as geology, meteorology, and astronomy.

General Curriculum Outcome 4:

Attitudes—*Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.*

Attitudes refer to generalized aspects of behaviour that are modelled for students by example and reinforced by selective approval. Attitudes are not acquired in the same way as skills and knowledge. They cannot be observed at any particular moment, but are evidenced by regular, unpromoted manifestations over time. Attitude development is a lifelong process that involves the home, the school, the community, and society at large. The development of positive attitudes plays an important role in students' growth by interacting with their intellectual development and by creating a readiness for responsible application of what they learn.

The attitudes outcome focusses on six ways in which science education can contribute to attitudinal growth. These have been articulated as statements or attitude indicators that have guided the development of the key-stage outcomes. They have also provided links to the STSE and skills general curriculum outcomes.

Appreciation of science

Students will be encouraged to appreciate the role and contributions of science in their lives, and to be aware of its limits and impacts. Science education can contribute to attitudinal growth when students are encouraged to examine how science has an impact daily and over the long term on themselves and on the lives of others. In this way, students can increasingly appreciate science's potential significance for their own lives.

Interest in science

Students will be encouraged to develop enthusiasm and continuing interest in the study of science. Science education can contribute to attitudinal growth when students are involved in science investigations and activities that stimulate their interests and curiosity, thus increasing their motivation for learning and encouraging them to become interested in preparing for potential science-related careers or furthering other science-related interests.

Scientific inquiry

Students will be encouraged to develop attitudes that support active inquiry, problem solving, and decision making. Science education can contribute to attitudinal growth when students are provided with opportunities for development, reinforcement, and extension of attitudes that support scientific inquiry, such as open-mindedness and flexibility, critical-mindedness and respect for evidence, initiative and perseverance, and creativity and inventiveness.

Collaboration

Students will be encouraged to develop attitudes that support collaborative activity. Science education can contribute to attitudinal growth when students are provided with opportunities to work in group situations and on real-life problems, thus developing a sense of interpersonal responsibilities, an openness to diversity, respect for multiple perspectives, and an appreciation of the efforts and contributions of others.

Stewardship

Students will be encouraged to develop responsibility in the application of science and technology in relation to society and the natural environment. Science education can contribute to attitudinal growth when students are involved in activities that encourage responsible action toward living things and the environment, and when students are encouraged to consider issues related to sustainability from a variety of perspectives.

Safety

Students will be encouraged to demonstrate a concern for safety in science and technology contexts. Science education can contribute to attitudinal growth when students are encouraged to assess and manage potential dangers and apply safety procedures, thus developing a positive attitude toward safety.

KEY-STAGE CURRICULUM OUTCOMES

Key-stage curriculum outcomes are statements that identify what students are expected to know and be able to do by the end of grades 2, 5, 8, 10 and 12 as a result of their cumulative learning experiences in science.

The key stages are established to coincide with the most common school organization. On the surface these stages are discrete, separate divisions used primarily for planning curriculum. However, in the continuum of an individual student's learning experience, the transition from grade 3 to grade 4 is not substantially different from the transition from grade 4 to grade 5. Furthermore, the key-stage outcomes represent what is intended or what is expected at the end of that stage. At the end of a particular key stage some students will have fully achieved the intended outcome while others will not. While the outcomes are intended for all students, it is acknowledged that different students will achieve these outcomes in different ways and to different depth and breadth depending on interest, ability, and context.

The key-stage outcomes presented in the following pages were taken from the Pan-Canadian framework document, *Common Framework of Science Learning Outcomes K-12*. The number attached to each outcome links the statement to both the Pan-Canadian framework and the curriculum guides that will be written. The numbering system is not meant to imply order of importance.

Key-Stage Curriculum Outcomes

Science, Technology, Society, and the Environment (STSE)

Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

By the end of grade 2 (STSE/knowledge), students will be expected to

investigate objects and events in their immediate environment, and use appropriate language to develop understanding and to communicate results (100)

demonstrate and describe ways of using materials and tools to help answer science questions and to solve practical problems (101)

describe how science and technology affect their lives and those of people and other living things in their community (102)

undertake personal actions to care for the immediate environment and contribute to responsible group decisions (103)

By the end of grade 5, students will have achieved the outcomes for entry–grade 2 and will also be expected to

demonstrate that science and technology use specific processes to investigate the natural and constructed world or to seek solutions to practical problems (104)

demonstrate that science and technology develop over time (105)

describe ways that science and technology work together in investigating questions and problems and in meeting specific needs (106)

describe applications of science and technology that have developed in response to human and environmental needs (107)

describe positive and negative effects that result from applications of science and technology in their own lives, the lives of others, and the environment (108)

Science, Technology, Society, and the Environment (STSE)

Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

By the end of grade 8, students will have achieved the outcomes for entry–grade 5 and will also be expected to

describe various processes used in science and technology that enable people to understand natural phenomena and develop technological solutions (109)

describe the development of science and technology over time (110)

explain how science and technology interact with and advance one another (111)

illustrate how the needs of individuals, society, and the environment influence and are influenced by scientific and technological endeavours (112)

analyse social issues related to the applications and limitations of science and technology, and explain decisions in terms of advantages and disadvantages for sustainability, considering a few perspectives (113)

By the end of the grade 10, students will have achieved the outcomes for entry–grade 8 and will also be expected to

describe and explain disciplinary and interdisciplinary processes used to enable us to understand natural phenomena and develop technological solutions (114)

distinguish between science and technology in terms of their respective goals, products, and values and describe the development of scientific theories and technologies over time (115)

analyse and explain how science and technology interact with and advance one another (116)

analyse how individuals, society, and the environment are interdependent with scientific and technological endeavours (117)

evaluate social issues related to the applications and limitations of science and technology, and explain decisions in terms of advantages and disadvantages for sustainability, considering a variety of perspectives (118)

By the end of the grade 12, students will have achieved the outcomes as stated for grade 10, but in specific elective science courses.

Skills

Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

By the end of grade 2, students will be expected to	By the end of grade 5, students will have achieved the outcomes for entry–grade 2 and will also be expected to
ask questions about objects and events in the immediate environment and develop ideas about how those questions might be answered (200)	ask questions about objects and events in the local environment and develop plans to investigate those questions (204)
observe and explore materials and events in the immediate environment and record the results (201)	observe and investigate their local environment and record the results (205)
identify patterns and order in objects and events studied (202)	interpret findings from investigations using appropriate methods (206)
work with others and share and communicate ideas about their explorations (203)	work collaboratively to carry out science-related activities and communicate ideas, procedures, and results (207)

Skills

Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

By the end of grade 8, students will have achieved the outcomes for entry–grade 5 and will also be expected to

ask questions about relationships between and among observable variables and plan investigations to address those questions (208)

conduct investigations into relationships between and among observations, and gather and record qualitative and quantitative data (209)

analyse qualitative and quantitative data and develop and assess possible explanations (210)

work collaboratively on problems and use appropriate language and formats to communicate ideas, procedures, and results (211)

By the end of grade 10, students will have achieved the outcomes for entry–grade 8 and will also be expected to

ask questions about observed relationships and plan investigations of questions, ideas, problems, and issues (212)

conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information (213)

analyse data and apply mathematical and conceptual models to develop and assess possible explanations (214)

work as a member of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results (215)

By the end of grade 12, students will have further developed the skills achieved by the outcomes stated for entry–grade 10.

Knowledge

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

By the end of grade 2, students will be expected to

From entry to Grade 2, STSE and knowledge outcomes are combined in the STSE section.

By the end of grade 5, students will have achieved the outcomes for entry–grade 2 and will also be expected to

describe and compare characteristics and properties of living things, objects, and materials (300)

describe and predict causes, effects, and patterns related to change in living and non-living things (301)

describe interactions within natural systems and the elements required to maintain these systems (302)

describe forces, motion, and energy and relate them to phenomena in their observable environment (303)

Knowledge

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

By the end of grade 8, students will have achieved the outcomes for entry–grade 5 and will also be expected to

Life Science
explain and compare processes that are responsible for the maintenance of an organism's life (304)

explain processes responsible for the continuity and diversity of life (305)

describe interactions and explain dynamic equilibrium within ecological systems (306)

Physical Science
describe the properties and components of matter and explain interactions between those components (307)

describe sources and properties of energy, and explain energy transfers and transformations (308)

recognize that many phenomena are caused by forces and explore various situations involving forces (309)

Earth and Space Science
explain how Earth provides both a habitat for life and resource for society (310)

explain patterns of change and their effects on Earth (311)

describe the nature and components of the solar system (312)

By the end of grade 10, students will have achieved the outcomes for entry–grade 8 and will also be expected to

Life Science
There will be other specific outcomes for (304) and (305)

explain processes responsible for the continuity and diversity of life (312)

evaluate relationships that affect the biodiversity and sustainability of life within the biosphere (318)

describe and predict the nature and effects of changes to terrestrial systems (331)

Physical Science
There will be other specific outcomes for (307) and (308)

analyse and describe relationships between force and motion (325)

identify and explain the diversity of organic compunds and their impact on the environment (319)

illustrate and explain the various forces that hold structures together at the molecular level, and relate the properties of matter to its structure (321)

Earth and Space Science
Further study of (312)

describe and predict the nature and effects of changes to terrestrial systems (331)

continued

Knowledge

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

By the end of grade 12, students will have achieved the outcomes for entry–grade 10 and will also be expected to

Life Science

compare and contrast the reproduction and development of representative organisms (313)

determine how cells use matter and energy to maintain organization necessary for life (314)

demonstrate an understanding of the structure and function of genetic material (315)

analyse the patterns and products of evolution (316)

compare and contrast mechanisms used by organisms to maintain homeostasis (317)

evaluate relationships that affect the biodiversity and sustainability of life within the biosphere (318)

Chemistry

identify and explain the diversity of organic compounds and their impact on the environment (319)

demonstrate an understanding of the characteristics and interactions of acids and bases (320)

illustrate and explain the various forces that hold structures together at the molecular level, and relate the propertied of matter to its structure (321)

use the redox theory in a variety of contexts related to electrochemistry (322)

develop an understanding of solutions and stoichiometry in a variety of contexts (323)

predict and explain energy transfers in chemical reactions (324)

Physics

analyse and describe relationships between force and motion (325)

analyse interactions within systems, using the laws of conservation of energy and momentum (326)

predict and explain interactions between waves and with matter, using the characteristics of waves (327)

explain the fundamental forces of nature, using the characteristics of gravitational, electric, and magnetic fields (328)

analyse and describe different means of energy transmission and transformation (329)

Earth and Space Science

demonstrate an understanding of the nature and diversity of energy sources and matter in the universe (330)

demonstrate an understanding of the relationships among systems responsible for changes to the Earth's surface (332)

describe the nature of space and its components and the history of the observation of space (333)

ATTITUDES

Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

By the end of grade 2, students will be expected to

recognise the role and contribution of science in their understanding of the world (400)

show interest in and curiosity about objects and events within the immediate environment (401)

willingly observe, question, and explore (402)

consider their observations and their own ideas when drawing a conclusion (403)

appreciate the importance of accuracy (404)

be open-minded in their explorations (405)

work with others in exploring and investigating (406)

be sensitive to the needs of other people, other living things, and the local environment (407)

show concern for their own safety and that of others in carrying out activities and using materials (408)

By the end of grade 5, students will have achieved the outcomes for entry–grade 2 and will also be expected to

appreciate the role and contribution of science and technology in their understanding of the world (409)

realize that the applications of science and technology can have both intended and unintended effects (410)

recognize that women and men of any cultural background can contribute equally to science (411)

show interest and curiosity about objects and events within different environments (412)

willingly observe, question, explore, and investigate (413)

show interest in the activities of individuals working in scientific and technological fields (414)

consider their own observations and ideas as well as those of others during investigations and before drawing conclusions (415)

appreciate the importance of accuracy and honesty (416)

demonstrate perseverance and a desire to understand (417)

work collaboratively while exploring and investigating (418)

be sensitive to and develop a sense of responsibility for the welfare of other people, other living things, and the environment (419)

show concern for their own safety and that of others in planning and carrying out activities and in choosing and using materials (420)

become aware of potential dangers (421)

ATTITUDES

Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

By the end of grade 8, students will have achieved the outcomes for entry–grade 5 and will also be expected to

appreciate the role and contribution of science and technology in our understanding of the world (422)

appreciate that the applications of science and technology can have advantages and disadvantages (423)

appreciate and respect that science has evolved from different views held by women and men from a variety of societies and cultural backgrounds (424)

show a continuing curiosity and interest in a broad scope of science-related fields and issues (425)

confidently pursue further investigations and readings (426)

consider many career possibilities in science- and technology-related fields (427)

consider observations and ideas from a variety of sources during investigations and before drawing conclusions (428)

value accuracy, precision, and honesty (429)

persist in seeking answers to difficult questions and solutions to difficult problems (430)

work collaboratively in carrying out investigations as well as in generating and evaluating ideas (431)

be sensitive and responsible in maintaining a balance between the needs of humans and a sustainable environment (432)

project, beyond the personal, consequences of proposed actions (433)

show concern for safety in planning, carrying out, and reviewing activities (434)

become aware of the consequences of their actions (435)

ATTITUDES

Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

By the end of grade 10, students will have achieved the outcomes for entry–grade 8 and will also be expected to

value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not (436)

appreciate that the applications of science and technology can raise ethical dilemmas (437)

value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds (438)

show a continuing and more informed curiosity and interest in science and science-related issues (439)

acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research (440)

consider further studies and careers in science and technology-related fields (441)

confidently evaluate evidence and consider alternative perspectives, ideas, and explanations (442)

use factual information and rational explanations when analysing and evaluating (443)

value the processes for drawing conclusions (444)

work collaboratively in planning and carrying out investigations, as well as generating and evaluating ideas (445)

have a sense of personal and shared responsibility for maintaining a sustainable environment (446)

project the personal, social, and environmental consequences of a proposed action (447)

want to take action for maintaining a sustainable environment (448)

show concern for safety and accept the need for rules and regulations (449)

be aware of the direct and indirect consequences of their actions (450)

By the end of grade 12, students will have further opportunity to develop attitudes as expressed by outcomes for entry–grade 10.

Contexts for Learning and Teaching

PRINCIPLES OF LEARNING AND TEACHING SCIENCE

The central goal of science education is scientific literacy. All activities that fall under the umbrella of instruction should therefore be aimed at that central goal. While curricula can be designed to encourage the development of scientific literacy, it is the instructional environment that must bring curricula to reality. The instructional environment will determine the congruity between the intended curriculum and the actual curriculum.

There are two overriding philosophies that should pervade all instruction (teaching/learning) in science. One of these philosophies, **resource-based learning,** is not specific to science instruction but is applicable to all teaching and learning. The second, the **science-technology-society-environment** connection, is a curriculum approach and an instructional approach that addresses all the goals of science education.

The instructional environment represents much more than the physical setting in which teaching and learning take place. While the physical environment is important, the intellectual environment in which teaching and learning take place is more important. Glickman (1991) states that *"Effective teaching is not a set of generic practices, but instead is a set of context-driven decisions about teaching. Effective teachers do not use the same set of practices for every lesson ... Instead, what effective teachers do is constantly reflect about their work, observe whether students are learning or not, and, then adjust their practice accordingly."* (p. 6)
All instructional practices must reflect the nature of science and how children learn science. Underlying every model of teaching/learning that actively involves learners in the process is the theory of constructivism—the view that knowledge is constructed in the mind of the learner, rather than transferred intact from the mind of the teacher to the mind of the learner.

STSE IN THE CLASSROOM

General Curriculum Outcome 1 (STSE) states that students will develop an understanding of the nature of science and technology, their applications and implications, and the relationships among science, technology, society, and the environment. However, STSE also refers to an approach to the teaching of science. This approach to science education has been advocated by many groups within both the science and science education communities.

STSE science places the scientific endeavour in the context of a contemporary societal or environmental situation, question, or problem. The desire to investigate the situation, answer the question, or solve the problem creates in the students a meaningful context in which to address the skills, concepts, and understandings of the course. The STSE approach aims to supply this organization through providing a relevant context. The STSE approach also allows the curriculum to reflect more accurately the current understanding of the nature of science, the nature of technology, and STSE interrelationships.

The following categories of STSE involvement in the curriculum are based on the work of Aikenhead (1990):

1. **Motivation by STSE Content**

Standard school science, plus a mention of STSE content in order to make a lesson more interesting. Students are not assessed on the STSE content.

2. **Casual Infusion of STSE Content**

Standard school science, plus a short study (2 hours) of STSE content attached to the science topic. The STSE content does not follow cohesive themes. Students are assessed almost completely on pure science content and only superficially on STSE content.

3. **Purposeful Infusion of STSE Content**

Standard school science, plus a series of short studies of STSE content integrated into science topics, in order to systematically explore the STSE content. Students are assessed to some degree on their understanding of the STSE content.

4. **Singular Discipline through STSE Content**

STSE content as an organizer for the science content and its sequence. The science content is selected from one science discipline. A listing of pure science topics looks quite similar to a category 3 science course, though the sequence would be quite different. Students are assessed on their understanding of the STSE content, but not as extensively as they are on the pure science content.

5. **Science through STSE Content**

STSE content as an organizer for the science content and its sequence. The science content is multidisciplinary, as dictated by the STSE content. A listing of pure science topics looks like a selection of important science topics from a variety of standard science courses. Students are assessed on their understanding of the STSE content, but not as extensively as they are on the pure science content.

Research indicates that significant increases in scientific literacy occur when the STSE component of the course is at the third level or beyond. Unless there is a purposeful application of STSE principles, and they are included in the formal evaluation scheme, then much of the benefit of STSE is lost.

The use of STSE in the organization of curriculum and the creation of learning situations is not new. Teachers have always provided students with opportunities to view science from some meaningful context. This meaningful context encourages more students to engage actively in making sense of the topic and allows the students to make personal connections to the topic under study. STSE attempts to provide this meaningful context.

An STSE context can be used in two general ways. The first is following the normal sequence of instruction. In this case, the STSE problem or situation causes the students to analyse, synthesize, or evaluate a new situation or solve a problem. The students' understanding of the science content and concepts is clarified and strengthened as they attempt to apply their existing knowledge in the context of complex STSE situations. This also allows students to be exposed to STSE issues and make the types of connections between science, technology, society, and the environment that were previously identified.

The second type of STSE context results in a re-organization of science curriculum to establish connections.

The net result of this process is a science curriculum based on how students learn, rather than on the traditional view of science as a field of study. This restructuring of the scope and sequence begins with a societal problem or situation. To solve the problem or understand the situation, students address a series of questions requiring knowledge of certain content, concepts, and skills in the areas of science and technology. The societal issue chosen suggests a matching piece of technology to examine and also determines which concepts are to be investigated and understood. Approached in this fashion, the core science material is constructed and understood within the meaningful context of attempting to investigate or solve a societal problem.

CONSTRUCTIVISM

In the last two decades many writers have called for major changes in the aims and pedagogy of science education (Alberta Education 1990; Dawson 1992; A.A.A.S. 1989). They argue that traditional science education has dealt mainly with the memorization, and to some extent, the application of science content. Current curriculum researchers and developers are working with teachers to focus on the acquisition of those science concepts and principles that are fundamental to understanding the world.

The constructivist perspective holds that meaningful learning or understanding is constructed in the mind of the learner as a result of interactions between sense impressions and the learner's previous understanding (Appleton 1993; Posner, Strike, Hewson & Gerzog 1982; Saunders 1992). Constructivists see the learner as a naive scientist who attempts to explain new events and phenomena by creating rules and hypotheses. Thus the learner has a set of cognitive structures (ideas) that help to explain the world around him/her. However, as new experiences are encountered the learner may find that his/her existing rules and hypotheses are insufficient to explain everything. Thus, the learner may have to add new ideas or make adjustments to existing ones to get the necessary explanations.

This adding or adjusting of ideas or cognitive structures was made famous by Piaget. He defined intelligence as an individual's ability to adapt to the environment. He argued that two processes were key to this adaptation: assimilation and accommodation. Assimilation was his name for the addition of new cognitive structures that were consistent with the existing ones. Accommodation was the term used for reshaping of the structures (conceptual framework) based on disparities between the existing structures and new experiences. Piaget believed that acquisition of concepts and intellectual growth proceeded slowly, since much thought is needed for the learner to understand complex phenomena in light of the existing structures, reflect on the match, and make adjustments to the structures that allow for an improved match with the sense perceptions of reality.

Science is often seen as an appropriate subject for the application of constructivist principles, since the hypothesizing and testing of cognitive structures that are fundamental to cognitive growth in the constructivist scheme mirror the work of scientists. Therefore, many writers have argued that one of the major aims of science education should be the development of concepts in the minds of the students that would allow them to make sense of the world. However, science itself is a way of looking at and explaining the world. Thus, the acquisition of concepts to help explain a phenomenon is too broad an aim. The concepts that the learner develops should be consistent with those concepts that scientists already hold for that particular phenomenon (Appleton 1993; Saunders 1992).

The literature abounds with studies that have examined the concepts that science students use to explain natural phenomena (Erikson 1979; Hashwell, 1988; Lawson 1988; Stavy 1991). In the vast majority of cases the research has shown that science students, even very successful ones, hold concepts that are inconsistent with those held by the scientific community. These concepts have been referred to as misconceptions, alternative conceptions, naive conceptions, and intuitive frameworks or alternative frameworks. Eylon and Linn (1988) summarize the finding of such studies as follows:

"Empirical studies of many different domains indicate that students begin their study of science with strongly held conceptions about some phenomena, conflicting ideas about some phenomena, and little knowledge of other phenomena. Studies of students' everyday ideas and naive conceptions include examinations of conceptions held both before and after instruction. These investigations reveal that students' ideas are often inconsistent with the principles taught in science class and that students often maintain their ideas when incorporating information from instruction, thus fitting new information presented in science class into everyday views rather than altering their frameworks." (p. 253)

One reason that helps explain how strongly students hold on to their alternative concepts is that, *"To the learner, they make logical sense within the world view he has constructed out of his experience,"* (Saunders 1992, p. 137). If science teachers seek to impose their explanations of the world on the students by direct presentation and transmission teaching, they can expect to meet with little success.

The constructivist approach to science education involves the teacher and students in the search for explanations to make sense of new experiences and phenomena. The task of the teacher is to organize the curriculum and the classroom experience such that the student, in an attempt to make sense of the event under investigation, comes to invent, examine, and pass judgment on those scientific explanations that are normally "covered" in the course.

From entry to grade 6 this passing judgment is based essentially on the notion of viability; that is, an idea is accepted if it explains the phenomenon under investigation. At the higher grades this judgment process will evolve so that it will allow the teacher and the students to examine the important scientific principles involved in theory choice. These discussions and examinations will also assist in developing an understanding of the nature of science and the nature of scientific knowledge.

Driver and Leach (1992) identify the features that characterize a teaching and learning environment from a constructivist perspective:

- Learners are not viewed as passive but are seen as purposive and ultimately responsible for their own learning. They bring their prior conceptions to learning situations.
- Learning is considered to involve an active process on the part of the learner. It involves the construction of meaning and often takes place through interpersonal negotiation.
- Knowledge is not "out there" but is personally and socially constructed; its status is problematic. It may be evaluated by the individual in terms of the extent to which it "fits" with his or her experience, is coherent with other aspects of the individual's knowledge, and is consistent with the knowledge schemes within particular social groups.
- Teachers also bring their prior conceptions to learning situations, in terms of not only their subject knowledge, but also their views of teaching and learning. These can influence their way of interacting with students in classrooms.
- Teaching is not the transmission of knowledge but involves the organization of the situations in the classroom and the design of tasks in a way that enables students to make sense of the "ways of seeing" of the scientific community.
- The curriculum is not that which is to be learned, but a program of learning tasks, materials, resources, and discourse from which students construct their knowledge.

CREATING LINKAGES AMONG SCIENCE DISCIPLINES

There are a number of unifying ideas that represent a way of organizing and connecting scientific knowledge. These organizing concepts are not the exclusive domain of science for they apply as well in mathematics, technology, business, government and politics, education, law, and other domains. These unifying concepts are really ways of thinking rather than theories, discoveries, or knowledge. Although there is some variation in the literature, there is a degree of consistency; for the purpose of the Atlantic science curriculum the unifying concepts of ***change, diversity, energy, equilibrium, matter, models***, and ***systems*** will be used. For the most part, these concepts should not be taught as separate topics. At every opportunity the various unifying concepts should be brought up in the context of the science being studied. Only after accumulating a wealth of examples, illustrations, and experiences will students integrate their knowledge related to these abstract concepts into their thinking.

Change

Changes in systems occur in several distinct ways—as steady trends, in a cyclical fashion, irregularly, or in any combination of these patterns. Recognizing the type of change depends on observation and analysis of the system. One's perception of change comes from one's experience with time.

A steady trend is a change that occurs in the same direction and can be described in simple mathematical terms. Examples of this type of change include an individual's growth and development, pond succession, or the steady increase in world population growth. A cyclical change is a sequence of changes repeated over time, for example, the cyclical changes that occur in climate. Cyclical change is characterized by a range in variation, a set length of time over which the cycle occurs, and the timing of peaks within the cycle. This type of change is commonly found in systems with feedback loops. Although they may not understand the reasons for it, young students will know that the changing of the seasons is a cyclical phenomenon. An irregular trend is one that appears random at first inspection, but is actually a disguised trend or cycle. The ability to discern the trend depends on the method of observation. Statistical analysis is often used to establish a pattern from measurable data. New branches of mathematics such as chaos theory and fractal geometry are attempting to uncover the underlying patterns in irregular changes. It appears that there are hierarchies of change patterns. Identifying the type of change can lead to more accurate predictions and, therefore, perhaps some degree of control of the change that may be of value in the design of technological systems, for example.

On a sufficiently small scale all change appears to have a random component. This phenomenon is termed chaos. Although details may be unpredictable, often, on a larger scale of observation, changes can be highly predictable. For example, components, individuals, or systems may go through much the same developmental sequences, but as in the formation of snowflakes or shorelines, the details are never the same twice.

Diversity

Students must develop an understanding and appreciation of the vast array of living and non-living forms of matter and the procedures used to understand, classify, and distinguish those forms on the basis of structure and function. This understanding can be developed only if students have concrete experiences with phenomena and objects before they encounter explanations and abstract theories.

At the entry to grade 3 level, this concept might be introduced through an examination of the variety in the kinds of materials (cloth, wood, stone, plastic, metal, etc.) or the variety of common animals with which students are already familiar. Progressively through the grades, diversity will be dealt with in an increasingly complex manner.

For example, the earth was under close scrutiny long before Darwin provided a new framework for explaining evolution and before the microscope led scientists to cells. Botanists, zoologists, geologists, surveyors, and explorers were the first to find out what was "out there." As information accumulated, interest in classification systems grew, and those systems became more complex, especially after microscopes, telescopes, and other tools revealed a whole new world to explore and catalogue. Eventually, scientists produced and tested the theories and models used to explain people's observations. They came to understand the natural world first through observations, then classifications, and then theories.

Energy

Energy is a central concept of the sciences. It is a bond linking scientific disciplines as diverse as agriculture, quantum physics, and oceanography. In the physical sciences, energy is perhaps the most important unifying concept because all physical phenomena and interactions involve energy. In the natural sciences, the flow of energy through individuals and ecosystems controls, maintains, and drives such diverse processes as photosynthesis, growth, metabolism, and trophic level interactions. Biochemistry is the study of how energy is organized by biochemical reactions that allow organisms to synthesize a variety of molecules essential for life. In the earth sciences, energies of the wind, precipitation, physical and chemical changes, as well as volcanic eruptions and continental drift, alter the face of the earth and are responsible for many geological processes.

The study of energy and its transformations, whether electrical, mechanical, chemical, thermal, or nuclear, is a unifying intellectual thread that stretches across all disciplines of science. Physicists study energetics, chemists study electron energy levels within and between atoms and energy of activation, and biologists study the energy absorbed or released in breaking or forming bonds. The unifying concept, energy, helps organize the facts of the various disciplines into patterns of study. For example, at the primary and elementary levels students will probably first understand that they get energy from the food they eat, and will be able to trace the source of that energy back to the sun. At the junior and senior high levels, students will be able to analyse more complex energy transformations, and will understand energy transformations at the molecular level.

Equilibrium

The child's first experience with this concept may appear at the playground where he/she, with a friend, attempts to find the right balance on the teeter-totter, thereby developing an intuitive understanding of equilibrium in that situation. Over time, this type of concrete experience will be supplemented by less obvious, even abstract, examples of the concept of equilibrium. Equilibrium is the state in which opposing forces or processes balance in a static or dynamic way. A system in which all processes of change appear to have stopped displays constancy or stability. There are two ways in which this can occur. A system in which the rate of input into the system is balanced by the rate of output, such that the system itself appears static, is in dynamic equilibrium. For example, within a capped bottle of club soda, molecules of water and carbon dioxide escaping from the solution into the air above increase in concentration until the rate of return to the liquid is as great as the rate of escape. The flow of water and carbon dioxide molecules in this example is a reversible process.

Some processes are not so readily reversible and therefore result in static equilibrium. This is a situation where all processes of change have stopped until something of sufficient magnitude is done to the system to disturb it and cause change. For example, a rock on the ledge of a cliff has the potential to fall farther down the cliff if an additional force of sufficient magnitude disturbs it.

Many aspects of a system are conserved. Once the boundaries of a system have been defined, the total amount of matter and energy within that system may not change, regardless of how much the system may change in other ways (e.g., form). For example, in an explosion of a charge of dynamite (in a contained explosion), the total mass, momentum, and energy of all products remains constant. Conservation is broken only when energy and/or matter pass through the boundary.

Matter

Matter is anything that has mass and can exist ordinarily as a solid, liquid, or gas. Animals and plants are organic matter; minerals and water are inorganic matter. The unifying idea of matter deals with two main components—the structure of matter and the cycling of matter in nature.

The scientific understanding of atoms and molecules requires combining two closely related ideas: all substances are composed of invisible particles, and all substances are made up of a limited number of basic ingredients, or "elements." These two merge into the idea that combining the particles of the basic ingredients differently leads to millions of materials with different properties. In developing this theme, students need to become familiar with the physical and chemical properties of many different kinds of materials through first hand experience before they can be expected to consider theories that explain them.

Living organisms are made of the same atomic components as all other matter; thus all of the principles that apply to the structure of matter in the physical (inorganic) world also apply to the organic world. Organisms are linked to one another and to their physical setting by the transfer and transformation of matter and energy. This basic concept connects the understandings from the physical, earth, and biological sciences.

The cycling of matter can be found at many levels of biological organization, from molecules to ecosystems. The study of food webs, for example, can start with the transfer of matter. An awareness of recycling, both in nature and in human societies, may play a helpful role in the development of thinking about the notion that matter continues to exist even though it changes from one form to another and moves from one place to another, but that it never simply appears out of nowhere and never just disappears. Students must understand that the recycling of matter involves the breakdown and reassembly of invisible units, rather than the creation and destruction of matter.

Models

Models are vehicles for suggesting how things work. Models serve as extremely useful tools for dealing with abstract ideas because they allow the ideas to become more concrete in nature and therefore easier to understand. From the earliest years, children understand that their toys are only representations of real-life objects, and their role-playing is another form of representing reality by pretending to be someone or something else.

There are two major types of models—physical and conceptual. Physical models use a "hands-on" approach. Examples include plans, drawings, devices, and pilot programs in a school. Conceptual models consist of mathematical representations of the essential components and their interactions (equations). Such models may, however, be applicable only under a narrow range of conditions. Conceptual models may also consist of analogies in which a system under investigation is likened to a system that is more familiar to the observer.

Models, regardless of type, represent a simplification of an idea or process. Only the essential components and interactions are identified. This is their major attribute, since in reality ideas and processes are often much too complex to deal with in detail. However, this aspect of a model can also be a negative feature: models may be misleading if essential components are left out. Models are designed to evolve based on their success as a representation of reality. As people's understanding of phenomena improves, models become more refined.

Systems

One of the essential components of higher-order thinking is the ability to think about a whole in terms of its parts and, alternatively, about parts in terms of how they relate to one another and to the whole. This type of thinking begins fairly early in a child's school experience as he/she begins to learn about, for example, some of the human body systems. Children, and many adults, accept on faith that inside their own bodies there are systems that have specific functions and that the whole body cannot function properly if one of these systems is not functioning properly.

A system is a collection of components that interact with one another so that the overall effect is much greater than that of the individual parts together. Examples of systems are political systems, transportation systems, the respiratory system, computer networks, and environmental ecosystems. The boundary of a system is defined by the observer and is dependent on the scale from which the observation is being made. For example, both the cell and the human body can be considered systems. The boundary of some systems, such as a rocky shore ecosystem, can often be difficult to establish. However, an increased understanding of a system can lead to a better definition of its boundaries.

Even with systems that have recognized boundaries, there is input and output of matter and/or energy through defined pathways and feedback loops (both positive and negative) that provide a measure of stability for the system. For example, the outputs of angiosperms in an ecosystem (fruit and oxygen) are inputs for some animals, while the outputs of animals (droppings and carbon dioxide) may serve as the inputs for plants. Change occurs in a system over time as rates of transfer into and out of the system change.

Systems interact with other systems. Systems also contain interactive subsystems. Whether a system is regarded as a system or a subsystem is dependent upon the scale of observation. Engineering concepts of inflow, outflow, system dynamics, and system change or evolution are often employed by scientists to clarify the components, dynamics, and interactions of systems. For example, air and fuel go into an engine and mechanical energy, exhaust, and heat come out, and material characteristics such as friction rates and technological calibrations determine the efficiency and life of the engine. Similar analyses can be done with circulatory systems, development of new material alloys, or computer networks.

RESOURCE-BASED LEARNING

As students and schools enter the twenty-first century, they find themselves in an era of rapidly increasing knowledge and changing technology. It is no longer adequate or realistic for students to acquire a select body of knowledge and expect it to meet their needs as citizens of the next century. The need for lifelong learning is shifting the emphasis from a dependence on the what of learning to the how of learning—today's students must learn how to learn. This is particularly true of the science curriculum, which addresses a body of knowledge that is expanding at a phenomenal rate.

This approach to learning is embodied in the philosophy of resource-based learning, which is identified by the following features:

- students actively participate in their learning
- learning experiences are planned based on curriculum outcomes
- learning strategies and skills are identified and taught within the context of relevant and meaningful units of study
- a wide variety of resources is used
- locations for learning vary
- teachers act as facilitators of learning, continuously guiding, monitoring, and assessing student progress
- teachers employ many different techniques to facilitate learning
- teachers work together to implement resource-based learning across grade levels and subject areas

Resource-based learning has many advantages. Placing students at the centre of the instructional process means that they will

- acquire skills and attitudes necessary for independent, lifelong learning (they learn how to learn—one of the fundamental aims of education)
- interact in group work, sharing and participating in a variety of situations
- think critically and creatively, experimenting and taking risks as they become independent and collaborative problem solvers and decision makers
- make choices and accept responsibility for these choices, thereby making learning more relevant and personal

The learning environment that encourages students to construct or reconstruct their knowledge must exhibit certain features including the following:

- ensuring the learning environment is a supportive one where learners feel able to contribute their ideas
- using group work as a basis for the social organization of the classroom so as to give students opportunities to think through and exchange ideas with peers
- ensuring that the teacher's role is a diagnostic one with an emphasis on listening to students to understand their thinking and then intervening, when appropriate, with suggested ideas or experiences to extend students' thinking

INSTRUCTIONAL SKILLS

Instructional skills are the most specific category of teaching behaviours. These are used constantly as part of the total process of instruction. They are necessary for procedural purposes and for structuring appropriate learning experiences for students. No matter how experienced or how effective a teacher may be, the development and refinement of instructional skills and processes is a continual challenge.

A variety of instructional skills and processes exist. Some are broader than others and more complex in nature. Some factors that may influence teacher selection and application of instructional skills include student characteristics, curriculum requirements, and instructional methods. Instructional skills include such activities as explaining, demonstrating, and questioning.

INVESTIGATIVE ACTIVITIES

While investigative activities are not unique to science, they are more commonly associated with science programs than with any other area of the curriculum. Investigative activities include a variety of activities ranging from the traditional experiment done in a science laboratory to a quick field trip to the school yard. All such activities are characterized by active student involvement in attempting to find answers to questions about the natural or constructed world. Many activities involve the use of scientific and technological tools and equipment; others simply involve observation using the senses. The investigation is a special instructional format that provides students with the opportunity to **do** science, not just **learn** science. Without activities of this sort it is extremely difficult, if not impossible, for students to develop an understanding of the nature of science, to develop the cognitive, scientific, and technical skills associated with doing science, or to construct the important ideas of science.

HOMEWORK

Homework is an essential component of the science program as it extends the opportunity for students to think scientifically and to reflect on ideas explored during class time. Meaningful and positive homework experiences can

- contribute to personal growth, self-discipline, and learning responsibility
- reinforce the ideas and processes students have learned or developed at school
- develop students' confidence in their ability to work without others' help
- provide opportunities for students to reflect on what they are learning and how well they are learning it

Homework provides an effective way to communicate with parents/guardians/caregivers and provides them with an opportunity to be involved actively in their child's learning. By ensuring that assignments model classroom practices and sometimes require parental input, teachers can help a parent/guardian/caregiver to gain a clearer understanding of the science curriculum and the progress of his or her child in relation to it.

Advocating science for all students means that the science curriculum must be designed and implemented to provide equal opportunities for each student according to his or her abilities, needs, and interests. Science provides a wealth of opportunities and experiences for all learners to understand themselves and the world around them. The needs of students often differ and these differences must be taken into account. This implies that special provision may be required to address individual needs.

SCIENCE PROGRAMS FOR EXCEPTIONAL STUDENTS

Exceptional students have special needs. Science teachers can make important contributions towards fulfilling these special needs whether the student is a delayed or gifted learner, or whether the student is mentally, socially, physically, or emotionally challenged. In a positive atmosphere and with ample time and consideration, exceptional students can attain much success in their science classes. Exceptional students, like all other students, develop positive self-images and self-esteem when they meet with success regularly. If science is taught as an inquiry, as a set of strategies for exploring ideas and answering questions, then, by its very nature, science can address the needs of a wide range of abilities. In attempting to help those students who have difficulties teachers can sometimes forget about the gifted learners who, because of their exceptional abilities, are capable of high achievement. These students require science programs that have been adapted to challenge them and enable them to fulfill their personal potentials.

Because some exceptional students may lack co-ordination, have difficulty in following sequential procedures, or have reduced sensory abilities, teachers often express concerns about safety. With some restructuring of the physical space, such as building a bench of suitable height for students in wheelchairs, using mechanical aids such as large plastic grips for manipulating test tubes, or encouraging peer partnerships, it is possible for students and teachers to have rewarding learning and teaching experiences. Every effort should be made to ensure that the fundamental right of every student to be given full opportunity for a broad education is met in all science classrooms and laboratories.

Because this document can address only basic principles of the rights of students with special needs, educators should refer to provincial, district and/or school policies that should provide more detailed guidelines.

GENDER EQUITY

On the surface, it may appear that there is no problem with the participation of females in science. Up to the senior high level all students participate in science. Furthermore, an analysis of the enrolment patterns in high school shows that the numbers of males and females in science courses are approximately equal. In addition, on the average, there is no significant difference in the achievement levels of males and females. However, a problem manifests itself when an analysis is made of post-secondary programs. The number of females graduating from science programs and continuing in science and science-related careers is significantly lower than the number of males.

While women have increased numerically in many fields of science in recent decades, they still face two stereotypes: as scientists they are unusual women, and as women they are unusual scientists. Since gender role stereotyping begins at an early age, it is important to pique girls' interest in science at the start of schooling. Parents and teachers need to be convinced that girls need science just as much as boys do and that they should provide role models for young girls interested in careers in science. What should be top priority is the transformation of schooling and the image of science so that the language, curriculum, packaging of the courses, and classroom teaching methods and interactions reflect the values and interests of women and empower girls and young women to develop fully their self-esteem. Emphasis needs to be shifted from a curriculum which does not reflect the values and interests of women to the implementation of a curriculum relevant to the entire population.

SCIENCE PROGRAMS FOR A MULTICULTURAL SOCIETY

Teachers of science should assist ethnically diverse communities to maintain their cultural and ethnic heritage, while sharing with other communities the commonly accepted values of equal opportunity for all in the political, social, and economic spheres of society.

The goals of science programs in a multicultural society follow:

- meeting the needs of racially visible and ethnically diverse learners
- developing in students positive attitudes toward cultural and linguistic diversity
- combatting racial prejudice and discrimination
- dispelling stereotyped views of other ethnic groups
- encouraging positive inter-cultural relationships
- facilitating an awareness of the inventions, discoveries, and contributions of scientists from a variety of ethnic and cultural backgrounds

Science is most often portrayed as the achievements of American and European males. The history of science needs to be part of a balanced science curriculum so students can see that all cultures have made great contributions to science. The Native peoples of Atlantic Canada, for example, developed an advanced understanding of naturally occurring compounds found in plants and animals before Europeans colonized the region. This type of knowledge has assisted the development of medicine, and many of these compounds are used in modern pharmaceuticals.

The foundations of science were built on the contributions of many cultures—Islam provided geometry and chemistry concepts; Egypt provided materials technology such as copper and glass; India developed surgical techniques and instruments; the Aztecs and Mayans contributed astronomical knowledge; tropical Africans developed advanced metallurgy; the Chinese invented the magnetic compass and gunpowder. Science classes that incorporate societal and technological components into their studies will help students to appreciate the contributions by other cultures to science. Science will then rightfully be viewed as a global accomplishment.

Different cultures bring a diversity of equally valid perspectives to their observations and interpretations. The study of environmental science, for example, is often pursued as a cause and effect study of sub-systems; however, many cultures employ a holistic view that focusses on system integrity. Environmental science can only benefit from a multiplicity of perspectives, especially given our global responsibility that requires ecological interdependence among nations.

Some fundamentalist Christian and Islamic groups as well as other groups may object to the teaching of evolutionary theory and scientific explanations of the origin of life. Teachers should acknowledge that there are many views of the origin of life. The scientific view should never be presented as the only explanation, but rather as the best explanation of scientists on the available evidence.

Subtle forms of racial stereotypes are often developed during the teaching of evolution by the depiction of early humans as technologically primitive, with dark pigmentation, while modern humans are portrayed as technologically advanced, with light pigmentation. All humans have achieved the same level of evolutionary "advancement," although each racial group has some characteristics that reflect adaptation to environmental conditions.

Adapting science programs for a multicultural society means that teachers must facilitate students' understanding of the

- limitations of scientific explanations and theories
- contributions all cultures have made toward the building of science
- key concepts that are essential to understanding oneself
- the cultural heritage science has contributed to people's understanding of the natural world

Science classes that encourage active learning and are respectful of students' ideas will facilitate equality of opportunity and will build students' confidence and motivation.

ASSESSING AND EVALUATING STUDENT LEARNING

> ***Assessment***
> *is the systematic process of gathering information on student learning.*

> ***Evaluation***
> *is the process of analysing, reflecting upon, and summarizing assessment information, and making judgments or decisions based upon the information gathered.*

Assessment and evaluation are essential components of teaching and learning in science. Without effective assessment and evaluation it is impossible to know whether students have learned, whether teaching has been effective, or how best to address student learning needs. The quality of the assessment and evaluation in the educational process has a profound and well-established link to student performance. Research consistently shows that regular monitoring and feedback are essential to improving student learning. What is assessed and evaluated, how it is assessed and evaluated, and how results are communicated send clear messages to students and others about what is really valued—what is worth learning, how it should be learned, what elements of quality are considered most important, and how well students are expected to perform.

ASSESSMENT

To determine how well students are learning, assessment strategies have to be designed to systematically gather information on the achievement of the curriculum outcomes. In planning assessments, teachers should use a broad range of strategies in an appropriate balance to give students multiple opportunities to demonstrate their knowledge, skills, and attitudes. Many types of assessment strategies can be used to gather such information, including, but not limited to, the following:

- formal and informal observations
- work samples
- anecdotal records
- conferences
- teacher-made and other tests
- portfolios
- learning journals
- questioning
- performance assessment
- peer assessment and self assessment

Teacher-developed assessments and evaluations have a wide variety of uses, such as

- providing feedback to improve student learning
- determining if curriculum outcomes have been achieved
- certifying that students have achieved certain levels of performance
- setting goals for future student learning
- communicating with parents about their children's learning
- providing information to teachers on the effectiveness of their teaching, the program, and the learning environment
- meeting the needs of guidance and administration personnel

EVALUATION

Evaluation involves teachers and others in analysing and reflecting upon information about student learning gathered in a variety of ways. This process requires

- developing clear criteria and guidelines for assigning marks or grades to student work
- synthesizing information from multiple sources
- weighing and balancing all available information
- using a high level of professional judgment in making decisions based upon that information

REPORTING

Reporting on student learning should focus on the extent to which students have achieved the curriculum outcomes. Reporting involves communicating the summary and interpretation of information about student learning to various audiences who require it. Teachers have a special responsibility to explain accurately what progress students have made in their learning and to respond to parent and student inquiries about learning.

Narrative reports on progress and achievement can provide information on student learning that letter or number grades alone cannot. Such reports might, for example, suggest ways in which students can improve their learning and identify ways in which teachers and parents/guardians/caregivers can best provide support.

Effective communication with parents/guardians/caregivers regarding their children's progress is essential in fostering successful home-school partnerships. The report card is one means of reporting individual student progress. Other means include the use of conferences, notes, and phone calls.

GUIDING PRINCIPLES

In order to provide accurate, useful information about the achievement and instructional needs of students, certain guiding principles for the development, administration, and use of assessments must be followed. *Principles for Fair Student Assessment Practices for Education in Canada* articulates five basic assessment principles:

- Assessment strategies should be appropriate for and compatible with the purpose and context of the assessment.
- Students should be provided with sufficient opportunity to demonstrate the knowledge, skills, attitudes, or behaviours being assessed.
- Procedures for judging or scoring student performance should be appropriate for the assessment strategy used and be consistently applied and monitored.
- Procedures for summarizing and interpreting assessment results should yield accurate and informative representations of a student's performance in relation to the curriculum outcomes for the reporting period.
- Assessment reports should be clear, accurate, and of practical value to the audience for whom they are intended.

These principles highlight the need for assessment which ensures that

- the best interests of the student are paramount
- assessment informs teaching and promotes learning
- assessment is an integral and ongoing part of the learning process and is clearly related to the curriculum outcomes
- assessment is fair and equitable to all students and involves multiple sources of information

While assessments may be used for different purposes and audiences, all assessments must give each student optimal opportunity to demonstrate what he/she knows and can do.

ASSESSING STUDENT LEARNING IN SCIENCE

Assessment and evaluation are essential components of learning and teaching in science. The Atlantic Canada science curriculum emphasizes having a classroom environment in which students will be encouraged to learn scientific processes and knowledge within meaningful contexts. It is important that assessment strategies reflect this emphasis and are consistent in approach. An assessment program which provides regular feedback, and is part of the learning process, is important to both student and teacher. Feedback tells students if they demonstrate understanding of scientific concepts and if their actions display expected performance levels for inquiry, decision-making, and problem-solving. Regular feedback inspires confidence in learning science and in becoming scientifically literate. Effective assessment of student learning in science provides educators with important information about the learning needs of individual students and the general achievement of the curriculum outcomes. It also permits teachers to monitor the effectiveness of learning opportunities, strategies employed and available resources.

The assessment of student learning must be aligned with curriculum outcomes and the types of learning opportunities made available to students. The Atlantic Canadian science curriculum provides suggestions for developing student learning across the four general curriculum outcome areas: science, technology, society and environment (STSE); skills; knowledge; and attitudes. These outcomes describe a balance of inquiry, problem-solving, and decision-making, within a suggested social/environmental context, for a given set of scientific knowledge. Over time, assessment should allow students to monitor their progress in various scientific skills: initiating and planning; performing and recording; analysing and interpreting; communication and teamwork. The curriculum calls for students to be actively involved in their learning, using the tools of science and of information processing during classroom/laboratory activities. These should be part of an assessment program which incorporates tasks similar to those used on a regular basis.

External Assessment
Administration of externally prepared assessments is on a large scale in comparison to classroom assessments, and often involves hundreds, sometimes thousands of students, allowing for use of results at the provincial, district and/or school levels. Depending on the comprehensiveness of the assessment, information can be used for all of the same purposes as classroom-based assessment, but it can also serve additional administrative and accountability purposes such as for admissions, placement, student certification, educational diagnosis, and program evaluation. External assessments offer common standards for assessment and for administration, scoring and reporting that allow for comparison of results over time.

As part of the regional agenda, development of external assessments in the core curriculum areas is being undertaken. Generally, external assessment includes assessments prepared by departments of education, national and international assessment groups, publishers, and research groups. Each provincial department of education makes decisions on whether or not to administer external assessments.

Program and System Evaluation
The results from both external and internal assessments of student achievement can be used, to varying degrees, for program and system evaluation. External assessment results, however, are more comparable across various groups and are therefore more commonly the basis for these types of evaluation.

In essence, the main difference between student evaluation and program and system evaluation is in how the results are used. In program evaluation marks or scores for individual students are not the primary focus of the assessment—it is the effectiveness of the program that is evaluated and the results are used to show the extent to which the many outcomes of the program are achieved.

When results are used for system evaluation, the focus is on how the various levels and groups within the system, such as classrooms, schools, districts, and so on, are achieving the intended outcomes. In many ways student and program evaluation are very much the same in that both emphasize obtaining student information concerning students' conceptual understanding, their abilities to use knowledge and reason to solve problems, and their abilities to communicate effectively.

One of the characteristics of the science curriculum that will help all students become scientifically literate is that it should utilize a wide variety of print and non-print resources that have been developed in an interesting and interactive style. Traditional print materials, laboratory equipment, and other materials, audio/visual resources, computer software, CD-ROMs, and videodisks should be an integral part of a student's learning experience.

SCIENCE EQUIPMENT AND SUPPLIES

The use of hands-on activities is an essential learning strategy in all science programs. Hands-on activities can range from simple demonstrations to complex scientific investigations or experiments. At any level of activity, in any learning environment, there exists a need for specific items of equipment or supplies. Such equipment should be appropriate to the grade level. For example, an expensive electronic analytical balance would be inappropriate for an early childhood science activity—a simple plastic platform balance would be adequate and more appropriate.

Some equipment and supplies must be obtained from commercial suppliers. Many other items can be homemade or improvised using everyday items. The provision of the latter type of equipment and supplies is an ideal way to involve parents/guardians/caregivers in their child's learning.

Whatever the needs and whatever the source of the equipment and supplies, teachers will need to be diligent in ensuring that appropriate materials are available so that students can engage in meaningful and relevant science activities. An associated concern, especially at the entry–grade 6 levels, is the storage of equipment and supplies. It may not be feasible for every classroom to have all the necessary material and some central storage may be necessary.

PRINT RESOURCES

Even with the advent of new media, print materials remain a dominant type of resource for science teaching and learning. There are a number of categories of print materials available to science teachers and students—teacher reference materials dealing with science teaching, student textbooks and accompanying teacher resources, science activity books containing ideas for experiments and/or demonstrations, science trade books and reference books (e.g., science encyclopedias), and supplementary science books that augment or complement science textbooks.

NON-PRINT RESOURCES

There is an increasing variety of resources in other formats such as video, computer software, CD-ROM, and videodisk. Computer software and CD-ROM disks offer simulations and models of real-life situations that permit the investigation of phenomena that are not available because of cost, safety, or accessibility. CD-ROM technology, with its tremendous storage capacity allows the advantage of significant depth and/or breadth of information on a single disk, a definite convenience for the teacher attempting to accumulate materials on a variety of science topics.

THE USE OF TECHNOLOGY

Just as computers and other technology play a central role in developing and applying scientific knowledge, they can also facilitate the learning of science. It follows, therefore, that technology should have a major role in the teaching and learning of science.

Computers and related technology (projection panels, CD-ROM players, videodisk players, analog-digital interfaces, graphing calculators) have become valuable classroom tools for the acquisition, analysis, presentation, and communication of data in ways that allow students to become more active participants in research and learning. In the classroom, such technology offers the teacher more flexibility in presentation, better management of instructional techniques, and easier record keeping. Computers and related technology offer students a very important resource for learning the concepts and processes of science through simulations, graphics, sound, data manipulation, and model building. These capabilities can improve scientific learning and facilitate communication of ideas and concepts. Lest the following emphasis on computers be misunderstood, it is asserted at the outset that computers and related technology should ***enhance***, but not replace, essential hands-on science activities.

The following guidelines are ***proposed*** for the implementation of computers and related technology in the teaching and learning of science:

- Tutorial software should engage students in meaningful interactive dialogue and creatively employ graphs, sound, and simulations to promote acquisition of facts and skills, promote concept learning, and enhance understanding.
- Simulation software should provide opportunities to explore concepts and models that are not readily accessible in the laboratory, e.g., those that require
  - expensive or unavailable materials or equipment
  - hazardous materials or procedures
  - levels of skills not yet achieved by the students
  - more time than is possible or appropriate in real-time classroom, e.g., population growth simulations.
- Analog-digital interface technology should be used to permit students to collect and analyse data as scientists do and perform observations over long periods of time, enabling experiments that otherwise would be impractical.
- Databases and spreadsheets should be used to facilitate the analysis of data by organizing and visually displaying information.
- Networking among students and teachers should be encouraged to permit students to emulate the way scientists work and, for teachers, to reduce teacher isolation.
- Using tools such as the World Wide Web should be encouraged as it provides instant access to an incredible wealth of information on any imaginable topic.

In order to effectively implement computers and other technology in science education, teachers should

- know how to use effectively and efficiently the hardware, software, and techniques described above
- know how to incorporate microcomputers and other technology into instructional strategies
- become familiar with the use of computer applications as management tools for grading, reports, inventories, budgets, etc.
- exemplify the ethical use of computers and software
- seek to provide equitable access for all students

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