

# Science and Technology

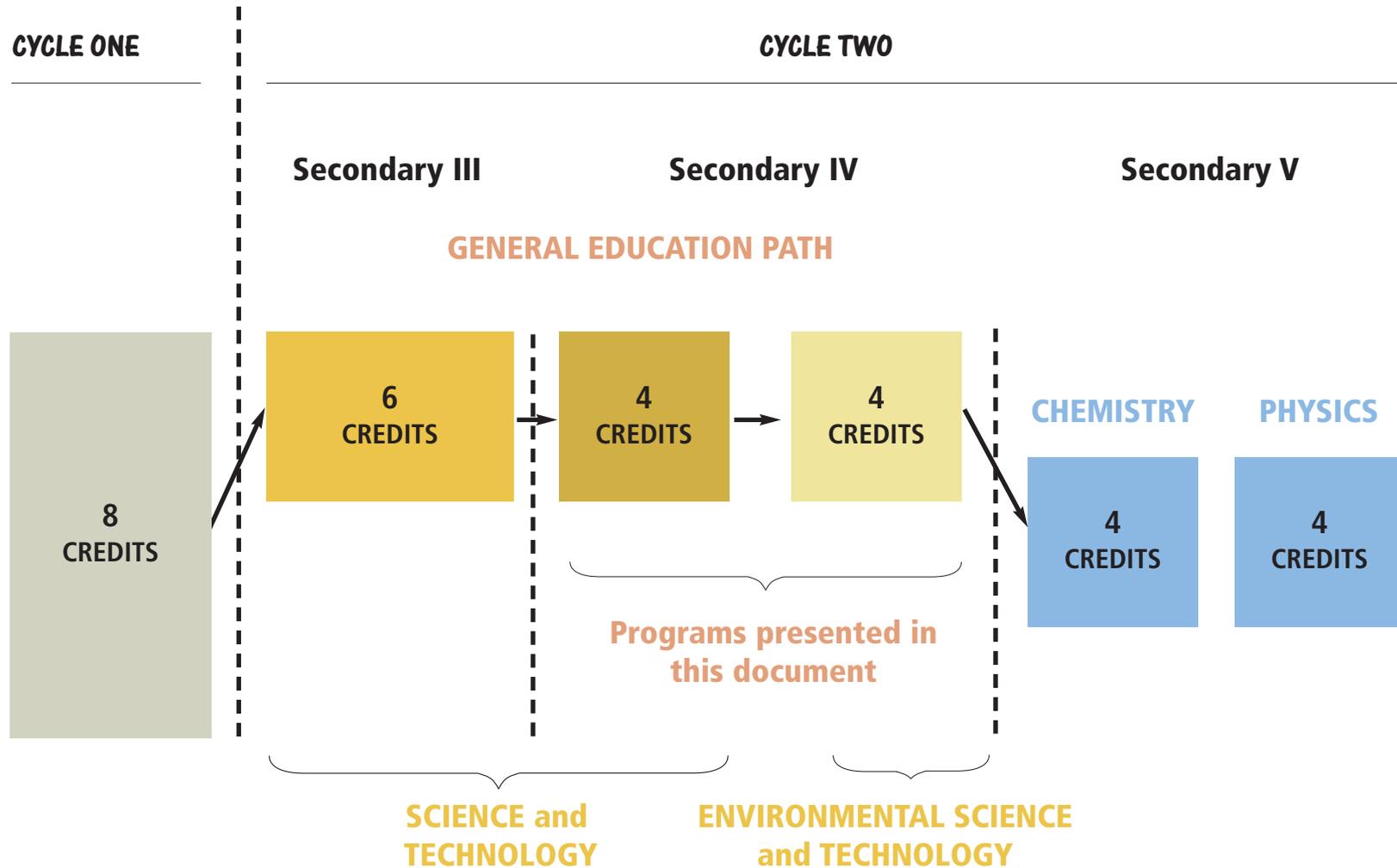
(Second Year of Secondary Cycle Two)

## Environmental Science and Technology



### Note to reader

This document presents the basic Science and Technology program and the optional Environmental Science and Technology program, both offered as part of the General Education Path for Year Two of Secondary Cycle Two. The optional Environmental Science and Technology program provides access to the optional Secondary V science and technology courses. This document is intended for teachers of the Science and Technology, and Environmental Science and Technology programs. The plain text refers to elements common to both programs, while the underlined text presents elements specific to the optional program.



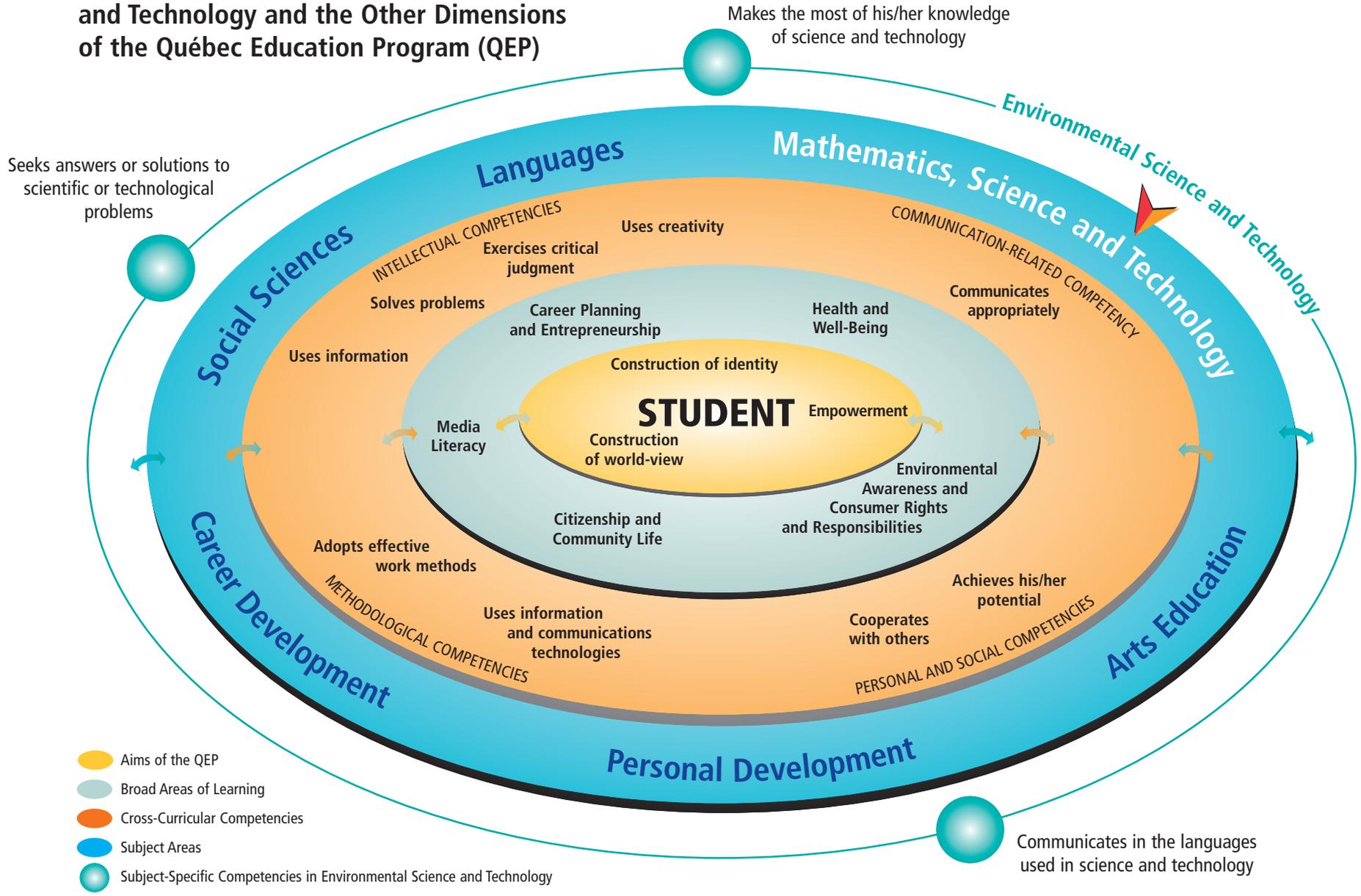
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# Making Connections: Environmental Science and Technology and the Other Dimensions of the Québec Education Program (QEP)



- Aims of the QEP
- Broad Areas of Learning
- Cross-Curricular Competencies
- Subject Areas
- Subject-Specific Competencies in Environmental Science and Technology



# Introduction to the Program

Science and technology are playing an increasingly important role in our lives and have made a key contribution to the transformation of societies. Their influence extends to a multitude of achievements that can be found everywhere in our environment. The associated methodologies and the knowledge they have generated apply to many different spheres of human activity.

Scientific and technological activities are embedded in the social and cultural context and are the result of a community's efforts to build new knowledge. As in other fields of activity, knowledge in these areas is not developed in a linear or cumulative manner. Strongly influenced by the social and environmental context in which it emerges, scientific and technological knowledge sometimes progresses slowly, through successive approximations, and sometimes expands by leaps and bounds; it may go through periods of stagnation, only to be followed by spectacular advances.

Faced with the rapid emergence of large amounts of complex scientific and technological knowledge and the proliferation of its applications, people must acquire specific knowledge, as well as strategies that enable them to adapt to new constraints. This requires that they view the achievements of science and technology in perspective and appreciate the impact, scope and limitations of this knowledge. It also requires the ability to adopt a critical attitude vis-à-vis the ethical questions raised by these issues.

## Vision of Science and Technology

Science is a means of analyzing the world around us. Its aim is to describe and explain certain aspects of our universe. Made up of a set of theories, knowledge, observations and methods, it is characterized by its attempt to develop simple, intelligible models to explain our complex world. These models can then be combined with existing models to arrive at increasingly complex visions. As we construct new knowledge, these theories and models are constantly being tested, modified and reorganized.

Technology, on the other hand, focuses more specifically on action that helps us interact with the environment of which we are an integral part. Its fields of application extend to every sphere of human activity. In fact, the word *technology* encompasses a wide variety of achievements, from the most simple to the most sophisticated. These include techniques, processes, tools, machines and materials.<sup>1</sup>

Technology aims to provide the ultimate in rigorously designed products and is based on scientific and nonscientific principles and concepts, depending on the needs it aims to meet. Nevertheless, it makes use of its own knowledge and practices. Its more pragmatic aspect leads to the development and use of more specific methods.

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*Technology focuses more specifically on action that helps us interact with the environment of which we are an integral part.*

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1. Examples of objects, systems, products and processes related to environmental issues can be found in Appendix B.

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Science and technology are becoming increasingly interdependent, so much so that it is often difficult to draw a clear line between the two. In its attempt to understand the world around us, science often relies on technological developments and achievements. Conversely, when technology seeks to meet a need by developing technical objects,<sup>2</sup> systems,<sup>3</sup> products<sup>4</sup> or processes,<sup>5</sup> it makes use of scientific principles, laws and theories and provides opportunities for their application.

Sometimes, technological advancements precede the scientific theories that explain them. Compasses had been in use for some time before the first modern study of magnetism took place. The first engines operated without the benefit of the study of thermodynamics, just as the first airplanes flew without the help of aerodynamic theory. In such cases, technology can provide extraordinary opportunities for exploration and questioning that lead to the development of new theories. The complementarity of science and technology can also be seen in their respective practical and design approaches to the physical world.

## The Concept of Environment

In these programs, the concept of environment refers to “a dynamic set of elements in a community that interact with the living organisms in that community.”<sup>6</sup> Thus there is not only one environment but many, defined by

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2. A *technical object* is a simple, practical object that has been manufactured (e.g. hammer, tweezers), as opposed to an object found in nature.
  3. In the technical sense of the term, a *system* is a set of more or less complex elements organized in such a way that they interact to meet a specific need (e.g. bicycle, dishwasher, heating and ventilation system).
  4. A *product* is a substance created by transformations effected by human beings (e.g. food product, beauty care product).
  5. A *process* is the means and method used to perform a task or obtain a result (e.g. technical, industrial, manufacturing process).
  6. Lucie Sauvé, *Pour une éducation relative à l'environnement : Éléments de design pédagogique*, guide de développement professionnel à l'intention des éducateurs (Montréal: Guérin, 1997), p. 45 [free translation].
  7. *Pour une éducation relative à l'environnement : Éléments de design pédagogique, guide de développement professionnel à l'intention des éducateurs*, p. 46 [free translation].

their component elements, their spatial and temporal boundaries, the types of organisms that live there, the types of relationships between them and so on. The environment is “closely related to all of the other dimensions of the human environment: political, economic, cultural, technological, etc.”<sup>7</sup> Thus, this program focuses on topics of particular concern to human beings, who are central to the problems addressed.

A product of human activity, the field of science and technology is closely related to, and can even change, the different environments it examines. The different elements of the environment can be the subject of scientific study. Consider, for example, environmental science, which groups together several fields of study and addresses the biophysical, relational and human aspects of the environment. Technology, which focuses more specifically on action, can influence the environment, living organisms and the interactions between them.

Finally, science and its resulting applications can have a major positive or negative impact on the environment. It is therefore important to take environmental concerns into account.

## Scientific and Technological Literacy

As integral parts of the societies they have played a major role in shaping, science and technology represent both an important aspect of our cultural heritage and a key factor in our social development. It is important to help students gradually develop their scientific and technological literacy and understand the role that such literacy plays in their ability to make informed decisions and in their discovery of the pleasures of science and technology.

Curiosity, imagination, the desire to explore and the pleasure of experimentation and discovery are just as much a part of scientific and technological activities as the need to acquire knowledge and understand, explain and create. In this regard, the field of science and

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technology is not the preserve of a small group of experts. We all have a certain degree of curiosity about the phenomena around us and a fascination with scientific and technological invention and innovation.

The history of science and technology is an integral part of this literacy and therefore should be drawn upon. It puts scientific discoveries and technological innovations in perspective and enriches our understanding of them.

Museums, research centres, engineering firms, healthcare facilities, local factories, businesses and other community organizations provide a wealth of resources for the development of scientific and technological literacy.

## The Programs

In Secondary Cycle Two, the Science and Technology and Environmental Science and Technology programs recommend four different approaches to teaching science and technology. The technocratic approach focuses on scientific skills. The democratic approach is more concerned with developing citizenship skills. The humanist perspective aims to help students develop their intellectual potential, while the utilitarian approach is based on the everyday uses of science and technology.<sup>8</sup> While the Science and Technology program reflects these perspectives without emphasizing any one of the four in particular, the Environmental Science and Technology program focuses on citizenship and scientific skills. Like the basic program, it pays special attention to the development of students' critical judgment. It aims to consolidate their scientific and technological learning and is a prerequisite for the optional science and technology programs offered in Secondary V.

The programs create a single discipline by integrating five scientific fields (astronomy, biology, chemistry, geology, physics) with technology. The curriculum is organized in this way because it is often necessary to refer to

8. Sylvie Barma and Louise Guilbert. "Différentes visions de la culture scientifique et technologique : défis et contraintes pour les enseignants," in Abdelkrim Hasni, Yves Lenoir and Joël Lebeaume (eds.), *La formation à l'enseignement des sciences et des technologies au secondaire dans le contexte des réformes par compétences* (Québec: Presses de l'Université du Québec, 2006), p.11-39.

subject matter and methods from several fields at once to solve various problems or form opinions about major scientific and technological issues.

The programs build on the previous programs and focus on the development of the same three competencies:

- Seeks answers or solutions to scientific or technological problems
- Makes the most of his/her knowledge of science and technology
- Communicates in the languages used in science and technology

These closely interrelated competencies are associated with various complementary aspects of science and technology (i.e. practical and methodological aspects; theoretical, sociohistorical and environmental aspects; and aspects relating to communication). Although the overall goals connected with these three competencies are

essentially the same at both the elementary and secondary levels, the requirements pertaining to their development become progressively more demanding in Secondary Cycle Two because of the higher complexity of the compulsory concepts.

The first competency focuses on the methodology used to solve scientific and technological problems. The students become familiar with concepts and strategies in a hands-on approach.

The students must ask themselves questions and solve problems through observations, hands-on activities, measurements, construction or experimentation, be it in a lab, a workshop or the real world.

The second competency focuses on the students' ability to conceptualize and apply what they have learned, especially in everyday life. They become familiar with the concepts involved in understanding various problems and analyzing the inner workings of technical objects and technological systems. These concepts are regarded as tools that help students gain a better understanding of the world and make informed judgments.

The third competency involves the different types of languages used in science and technology, which are essential for sharing information as well as interpreting and producing scientific or technological messages. It involves

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*The three competencies are developed together and not in isolation or sequentially. Evaluation, however, can focus on a single competency.*

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not only knowledge of specialized terminology and symbolism, but also the ability to use them intelligently, by learning, for example, to adapt one's level of language to a specific audience.

The students participate actively in exchanges using the languages of science and technology, in accordance with established rules and conventions.

These competencies are developed together and not in isolation or sequentially. In order to master scientific and technological methods, students need to know and be able to use the related concepts and languages. They become familiar with these methods in different contexts that give them meaning and importance. Evaluation, however, can focus on a single competency.

These competencies are inextricably linked to the topics covered in the program. Resources for developing these competencies are presented in the Program Content section, which includes the compulsory concepts covered in these programs. These concepts are related to various branches of science and technology divided into four areas: The Material World, The Living World, The Earth and Space and The Technological World.

# Making Connections: Science and Technology and the Other Dimensions of the Québec Education Program

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In a variety of ways, the science and technology programs for the Second Year of Secondary Cycle Two are related to the other dimensions of the Québec Education Program (i.e. the broad areas of learning, the cross-curricular competencies, mathematics and the other subject areas).

## Connections With the Broad Areas of Learning

Because of the ways in which science and technology affect human health and well-being, the environment and the economy, there is significant overlap between the issues and challenges associated with the broad areas of learning and those raised by scientific and technological discoveries and achievements.

### Health and Well-Being

The knowledge that students acquire in studying science and technology can help them answer health-related questions and makes a significant contribution to this broad area of learning. Scientific knowledge gives students the chance to learn more about the interactions between their body and the environment, which may encourage them to adopt healthy lifestyle habits. For example, they can study contaminants that could potentially accumulate in the food chain. The wide range of technological applications in the fields of health and the environment are a good source for creating learning and evaluation situations.

### Environmental Awareness and Consumer Rights and Responsibilities

Scientific and technological knowledge helps young people increase their awareness of specific issues pertaining to their environment, such as the use of natural resources, the impact of human activity on the environment, waste management, the resources available in different places, the globalization of the food industry and the ethical issues related to

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*The broad areas of learning are related to major issues of today. In its specific way of dealing with reality, each subject sheds a different light on these issues, helping students develop a broader world-view.*

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biotechnologies. Many advancements in science and technology have led to consumer habits that have various consequences for the environment. In establishing or analyzing an environmental balance sheet, students will study the social, ethical, economic or environmental impact of a project. The environmental balance sheet also encourages students to question their own consumer habits and to adopt responsible behaviour.

### Media Literacy

Whether to learn, to obtain information or to communicate, students use the various media with which they are already familiar. It is important that they

learn to take a more critical view of the information they find. They must become proficient in using media-related materials and communication codes and come to understand the growing impact the media have in society and in their own everyday lives. Teachers should make extensive use of these media. Movies, newspapers and television address scientific and technological topics that can be linked

to the students' everyday lives in many different ways. The current fascination with information and communications devices such as radios, televisions, computers, cell phones and communications satellites can be used to contextualize learning and increase students' motivation.

### Career Planning and Entrepreneurship

The variety of activities that students are asked to carry out in this program can help them better understand the nature of scientific and technological work and apply it to their personal planning.

Scientific and technological knowledge is required in a variety of employment sectors. Teachers can help students discover these sectors and determine their level of interest and aptitudes for them. In Secondary Cycle Two, these elements are particularly important, as the students will soon be called upon to make a career choice.

## Citizenship and Community Life

The scientific and technological literacy that students gradually acquire gives them a new perspective on certain social issues, which may improve the quality of their participation in the classroom, the school or society in general. Activities related to the environment, such as launching a campaign on residual materials management at the school, can be used to develop learning situations that can help students learn about responsible citizenship.

## Connections With the Cross-Curricular Competencies

The development and consolidation of scientific and technological literacy as described in these programs involves the development of subject-specific competencies, which is intimately linked with the development of cross-curricular competencies. In turn, the cross-curricular competencies considerably broaden the scope of the subject-specific competencies.

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*Cross-curricular competencies are not developed at a theoretical level; they are rooted in specific learning contexts, usually subject-related.*

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## Intellectual Competencies

Intellectual cross-curricular competencies play a crucial role in science and technology. The search for answers or solutions to scientific or technological problems requires that students use information judiciously and question the reliability of their sources. It also helps them develop new problem-solving skills and adapt them to specific situations. Considering alternative solutions in the design and development of a technical object or a technological system, developing and implementing a plan of action to solve a problem, and taking into account different views on a scientific or technological issue are all ways of using creativity.

Today's society is characterized by the emergence of pseudosciences. Students must therefore learn to exercise critical judgment, especially when analyzing advertisements, scientific opinions or the consequences of science and technology. They must try to keep media influences, social pressures and conventional wisdom in perspective in order to determine what has been validated by the scientific and technological community and what is being reported by other groups.

## Methodological Competencies

The precision associated with the methods used in these programs requires that students adopt effective work methods and comply with related standards and conventions.

The rapid development of information and communications technologies has played a significant role in recent advances in the world of science and technology. Using various technological tools (e.g. data-acquisition interfaces with sensors, computer-aided drafting, simulation software) in conducting experiments and solving scientific or technological problems helps students learn to use information and communications technologies. In addition, by joining a virtual scientific community, students can share information, communicate with experts on-line, present the results of their work and compare them with those of their peers by taking part in a discussion group or video conference.

## Personal and Social Competencies

When they take hypotheses or solutions into consideration, when they move from the abstract to the concrete or from decision to action, students are open to the range of human possibilities. They can see a greater variety of options and agree to take risks. With time, they learn to trust themselves and accept the fact that they can make mistakes, which allows them to achieve their potential.

To develop their knowledge of science and technology, students must cooperate with others, since the sharing of ideas or points of view; peer or expert validation; and various collaborative research, experimental or design and manufacturing activities are part and parcel of the learning process.

## Communication-Related Competency

Learning concepts and the inextricably linked scientific and technological languages enable students to develop their ability to communicate appropriately. They must gradually discover the codes and conventions of these languages and become familiar with their uses.

## Connections With the Other Subject Areas

To ensure that students receive an integrated education, it is important to connect scientific and technological learning to learning in other subjects. Any subject is defined, at least in part, by the way in which it perceives reality and by its particular view of the world. Other subjects can shed additional light on science and technology just as science and technology can help us gain a better understanding of other subjects.

### Mathematics, Science and Technology

The field of mathematics is closely related to the science and technology programs. It provides a body of knowledge useful for the study of science and technology. For example, when students follow a scientific or technological method, they must often measure, count, calculate averages, apply geometric concepts, visualize space and choose different types of representation. Mathematics is also useful to establish or analyze an environmental balance sheet, in which students must do calculations and convert units of measurement. It is also frequently used in the design of technical objects or technological systems, to model relations between variables. Its vocabulary, graphs, notation and symbols make mathematical language a tremendous asset to science and technology.

Mathematics requires the development of competencies involving reasoning, problem solving and communication, which are related to the competencies in the science and technology programs. Their combined use fosters the transfer of learning and the development of the cross-curricular competencies, in particular, the intellectual cross-curricular competencies. Science and technology also help students understand certain mathematical concepts, such as variables, proportional relationships, the principles of geometry and statistical concepts.

### Languages

The Languages subject area provides students with the tools essential to the development of their competencies in science and technology. Whether the students are reading, writing or communicating verbally, the

competencies they develop in English Language Arts are indispensable for interpreting information correctly, describing or explaining a phenomenon, or justifying a methodological decision. Moreover, the different terms used in science and technology, which are often specific to the field, help enrich the students' vocabulary. Finally, the ability to analyze or produce written or oral texts is closely related to Competency 3, *Communicates in the languages used in science and technology.*

A certain level of competency in French is indispensable for gaining access to information in French documents and media, which provide additional perspectives on the issues at hand. It is also an asset since French is used in many types of scientific and technological communications, both in Québec and elsewhere.

### Social Sciences

The study of scientific and technological developments can shed new light on the history of different societies, since the problems that prompted them were the result of specific and often complex and diversified social conditions. Conversely, the historical perspective makes it possible to contextualize developments in science and technology and determine their impact. Looking at the past can also help answer questions about the source of certain scientific explanations or technological achievements.

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*Reality can rarely be explained by concepts related to a single subject. Its multiple facets can only be understood by combining the different fields of knowledge.*

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### Arts Education

Science and technology benefit from the creativity promoted by arts education. Some of the methods used in these programs are related to the creative dynamic shared by the four arts education programs: Drama, Visual Arts, Dance and Music. This is particularly the case with observation strategies, which sometimes require ingenuity in order to obtain the data required; the formulation of hypotheses, which sometimes requires a certain amount of boldness; or the design of technological objects, which requires a sense of aesthetics. All of these activities require creativity.

In turn, science and technology contribute to a better understanding of the arts. For example, knowledge of the possible impact of certain products on

the environment could inspire artists to choose environmentally friendly products. Similarly, the ability to produce and share scientific and technological messages can be useful when creating media images in the Visual Arts program.

### Personal Development

The competencies developed in the Ethics and Religious Culture program can be of great use in studying science and technology, especially because of the many ethical questions examined such as the use of certain energy resources, the consequences of their transformation or the issues related to waste resulting from overconsumption.

Connections can also be made with Physical Education and Health. Healthy eating habits, energy management, the body's energy needs and health and safety are concerns related to both programs.

The science and technology programs can therefore easily be adapted to interdisciplinary activities. An integrated application of the different areas of learning in the Québec Education Program is recommended for a well-rounded education adapted to the realities of the 21st century.

## Pedagogical Context

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This section presents the pedagogical context conducive to the construction of scientific and technological knowledge and competencies. It addresses the teacher's and students' roles.

### Role of the Teacher

Four aspects of the teacher's role are addressed: developing or adapting meaningful learning and evaluation situations, guiding students in the process of competency development, evaluating the level of competency development and using certain strategies to teach environmental education.

### Developing or adapting meaningful learning and evaluation situations<sup>9</sup>

Two of the teacher's most important roles are to propose stimulating learning and evaluation situations and to choose teaching strategies based on pedagogical differentiation. As much as possible, teachers should base these situations on current issues associated with one or more focuses of development of a broad area of learning. The situations addressed in these programs deal with environmental issues.

This section presents the characteristics of learning and evaluation situations, the type of situations best suited to each competency, and possible resources.

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9. The examples of learning and evaluation situations in Appendix C illustrate how the proposed issues can be presented in class to help students give meaning to their learning and assimilate concepts in a meaningful context. The learning and evaluation situations involve a number of connections with the educational aims of the broad areas of learning, as well as with learning in other subjects. They also enable students to apply both cross-curricular and subject-specific competencies.

### Contextualized, open-ended and integrated situations

Contextualized, open-ended and integrated learning and evaluation situations help give meaning to learning and foster the integration of knowledge, skills and attitudes.

A situation is contextualized when it gives meaning to concepts by placing them in a context in which they are useful. For this reason, it deals with current events, scientific and technological achievements related to the students' everyday lives or the major issues of the day.

A situation is open-ended when it is based on information that can lead to different possible solutions. Teachers must be able to approach the problem in different ways and choose from among a variety of activities. The initial situation can involve complete, implicit or superfluous information. In cases

where there is not enough information to solve the problem, students will have to do additional research, which will contribute to their learning.

An integrated situation is based on knowledge, skills and concepts from more than one area of the program: The Living World, The Material World, Earth and Space, and The Technological World. It must also

be related to the educational aims of one or more broad areas of learning and, as much as possible, to other subject areas.

### Complex situations that enable students to develop competencies

To be able to use subject-specific competencies, students must first have mastered the compulsory concepts in these programs and in previous science and technology programs. Thus, the learning and evaluation situations should foster the acquisition of these concepts, while enabling students to develop the different aspects of the competencies involved. They must also encourage students to engage in practical activities such as experimentation and design, to formulate an opinion or to express their views on the issues addressed.

In order to help students develop Competency 1, *Seeks answers or solutions to scientific or technological problems*, teachers should propose learning and evaluation situations that encourage students to adopt a problem-solving approach involving the experimental method or the design process. These situations require a hands-on approach. Because of the risk inherent in handling certain instruments and substances, the intervention of competent individuals, such as lab technicians, may be required. The situations may also involve modelling or the observation or empirical method.

In order to help students develop Competency 2, *Makes the most of his/her knowledge of science and technology*, teachers should propose situations that encourage students to formulate opinions on a variety of complex environmental issues. Studying these issues will enable them to develop critical judgment and learn to qualify their arguments.

Finally, Competency 3, *Communicates in the languages used in science and technology*, is best developed in situations in which students must select an appropriate method of presentation, use adequate oral and written scientific and technological vocabulary, and make connections between concepts and their various graphic or symbolic representations. Teachers should always focus on the quality of oral and written language, whether in an oral presentation, a schematic diagram of a technical object or technological system, a written technical or lab report or an essay on the social impact of science and technology.

Teachers may decide to work on all three competencies at the same time, shifting the focus from one to the other. They should use different teaching strategies (e.g. problem-based approach, case study, debate, project) to help students adopt a reflective approach, asking questions and taking a step back to examine their procedure.

### Resources

A number of internal and external resources, including personal, information, material, institutional and human resources are used in the development of competencies. Personal resources include knowledge, skills, strategies, attitudes and techniques. Those that involve knowledge from a variety of subject areas are referred to as conceptual resources. Information resources include textbooks and other relevant documents and tools for finding information.

Material resources are instruments, tools and machines, as well as everyday objects. Institutional resources, i.e. public and parapublic agencies such as museums, research centres, engineering firms, healthcare facilities, local factories and businesses and other community organizations, provide a wealth of resources for the development of scientific and technological literacy.

Teachers are the most immediately accessible human resources. Like lab and workshop technicians, they are indispensable at a number of levels, especially as concerns laboratory and workshop safety. They can be assisted by teachers in other subjects or by different experts.

### Guiding students in the process of competency development

Another aspect of the teacher's role is to support students as they develop competencies. Teachers should guide students in their choices by focusing on those aspects of the process that, in their opinion, require more attention (e.g. building a model, designing a prototype,<sup>10</sup> providing an initial explanation, understanding the concept of variable, measuring, presenting results). Although the situations are open-ended, they must eventually be specifically defined in terms of a task that can be completed or a goal that can be achieved with the help of the appropriate resources and time built in for reflection. If students are asked to design a prototype, teachers should provide the necessary specifications. To save time, they can also provide manufacturing process sheets. Pre-prepared jigs could facilitate certain machining operations.

Teachers must adapt tasks to the students' level of competency, providing the necessary explanations, answering questions, proposing ideas for solving problems, providing less independent students with additional support and making sure that laboratory or workshop safety rules are followed. It is also important that students learn from their mistakes and understand that they are rarely due to chance.

10. Here, a prototype is any constructed object or device that could be mass-produced. It can be a design, manufacturing, production, experimental or trial prototype.

Teachers must provide students with a framework that is both flexible and rigorous. They must ensure that the students do not become overwhelmed by the quantity of information to be processed and encourage them to select the information needed for the task or problem at hand and to seek new information as well.

Teachers are always an important resource for students, particularly with respect to the regulation of learning and strategies involving the entire class. The latter can be an ideal opportunity for reframing learning and making connections between new and prior learning. Teachers also play an active role in reviewing and synthesizing learning.

### Evaluating the level of competency development<sup>11</sup>

Evaluating the level of competency development is another important role the teacher plays. According to the Policy on the Evaluation of Learning, evaluation in science and technology plays a dual role: to support learning and to recognize competencies.

#### Supporting learning

Teachers should observe students on a regular basis in order to help them adjust their approach and mobilize their resources more effectively. They should propose a variety of learning situations, each one accompanied by observation, evaluation or recording tools. In developing these situations and tools, they must rely on the evaluation criteria associated with the competencies in question. This will enable them to establish indicators and observable behaviours that will allow them to evaluate the level of competency development. They should also refer to the end-of-program outcomes and the scales of competency levels.

The teacher's goal should always be to enable students to discover and overcome their difficulties or to consolidate their learning. Teachers can observe students as they work and take immediate action. Observations can

11. See *Policy on the Evaluation of Learning: General Education in the Youth Sector, General Education in the Adult Sector, Vocational Training and Evaluation of Learning at the Secondary Level: Framework*, which provides useful information about the characteristics of learning and evaluation situations, pedagogical differentiation, the evaluation of cross-curricular competencies, marking, the scales of competency levels, the communication of results and evaluation planning.

also be recorded for the purpose of identifying each student's achievements and difficulties, reviewing with them the strategies used and the learning acquired, and adjusting the teaching approach as needed.

Finally, evaluation to support learning is also the students' responsibility. Thus the teacher should encourage self-evaluation, co-evaluation or peer evaluation, providing the necessary tools.

#### Recognizing competencies

To evaluate the level of competency development achieved by each student, teachers must have sufficient evidence on which to base their assessment. To ensure a valid assessment, they should refer to the evaluation criteria and end-of-program outcomes for each of the three competencies, as well as the scales of competency levels.

#### Teaching Environmental Education<sup>12</sup>

Focusing on environmental issues makes it possible to contextualize the learning of scientific and technological concepts, to address the social, political and ethical aspects of scientific and technological discoveries and innovations and to understand their meaning and scope.

Environmental education goes beyond the simple transmission of knowledge, enabling students to use their critical judgment to construct knowledge that can empower them. It is aimed at helping students adopt environmentally ethical attitudes, values and behaviours.

Environmental science and technology can be taught in different ways. The teacher can focus on the content with a view to helping students acquire knowledge about the environment; this is education **about** the environment. If the environment is seen as a pedagogical resource (context) for teaching science and technology, we speak of education **using** the environment. Education **for** the environment focuses on solving and preventing environment problems. Finally, education **in** the environment uses the

12. The concept of environmental education presented in this document is based on the work of researcher Lucie Sauvé: *Pour une éducation relative à l'environnement : Éléments de design pédagogique*, guide de développement professionnel à l'intention des éducateurs (Montréal: Guérin, 1997).

environment to define learning by making use of the school's surroundings (field instruction) or the biophysical or social context.

The environment itself can be studied from different angles, and teachers must determine the appropriate approach. It can be likened to nature, which is all around us, and which we must learn to appreciate, respect and preserve, or it can be seen as a living environment to be understood or manipulated, an environment that includes the biosphere and has an impact on long-term social relationships. It can also be seen as a space filled with problems to be prevented or solved, or as a system to be understood in order to be able to make enlightened decisions. Finally, the environment can be perceived as a resource to be managed and shared, and as an opportunity to become involved in a community project. Our relationship with the environment is entirely contextual and culturally determined, but it exists within a set of interrelated and complementary dimensions. Environmental education limited to one or the other of these dimensions would be incomplete and might perpetuate a biased view of our relationship with the environment.<sup>13</sup> Obviously, it would be impossible to address all of these dimensions in a single learning and evaluation situation. However, it is important to cover as broad a range as possible over the course of the year, taking advantage of the many contexts provided by the diversity of environmental issues.

### [Establishing or analyzing an environmental balance sheet and analyzing values associated with environmental issues](#)

Certain pedagogical strategies in environmental education are particularly well adapted to teaching science and technology. These include establishing or analyzing an environmental balance sheet and analyzing values associated with environmental issues.

Establishing or analyzing an environmental balance sheet makes it possible to assess the environmental impact of the operations associated with a technical object, system, product or process. These strategies can also apply to an individual, a group of individuals, an ecosystem, a country, etc. An environmental balance sheet is a quantification of the flow of matter and energy associated with the subject at hand. In the case of a product, this

refers to the energy resources required to extract the raw materials, transform them into usable components, manufacture intermediate and finished products, transport materials to each stage of transformation, manufacture the product in question, and distribute it, use it and dispose of it (recycling, reuse, incineration or transfer to a landfill site).

The environmental balance sheet must take several parameters into account. It requires students to reason, formulate hypotheses, infer information and propose solutions. It helps them assess the ecological footprint of a group of people (or that of an ecosystem, product, process, etc.) and to consider the impact on the environment and determine the appropriate action to take.

Environmental issues are based on conflicting values, and addressing them in a science and technology course will necessarily involve ethical discussions. Analyzing values will help students understand the emotional and moral aspects of an environmental issue. They must identify and evaluate the values underlying the positions of the various parties involved in a controversy. The analysis is based on an understanding of the emotional aspect of the conflict, but should be as objective as possible. At the same time, students can clarify and situate their own values with respect to those analyzed. This comparison will prove very useful in formulating an opinion.

It is important, however, that teachers avoid indoctrinating the students by consciously or unconsciously favouring certain points of view and ideas. Pedagogically speaking, studying an issue involves encouraging students to explore different aspects and viewpoints in order to formulate their own opinion.

## Role of the Student

Students must participate actively in learning situations that require critical judgment, initiative, creativity, autonomy and intellectual rigour. They must therefore construct and make use of a variety of personal resources (knowledge, techniques, skills, strategies and attitudes). If necessary, they may search for a range of information, select the material resources that might help them in their learning process or consult human resources in their immediate environment. In some cases, they might find it useful to go beyond the school and home. Experts, museums and businesses, as well as

13. Lucie Sauvé, "Environnement et consommation : Stimuler l'engagement et construire l'espoir," *Spectre*, vol. 36, no. 3 (Oct. 2006): 11.

the local community, provide an opportunity to explore the world and to consider other points of view.

Students should be able to use the appropriate techniques to carry out their plan of action. When they use verification or control instruments, they must take measurement errors into account, whether they are attributable to the instrument, the user or the environment. Measurements must be expressed

with the appropriate number of significant digits. They must also apply safety standards and work carefully in the lab or the workshop. When in doubt, they should ask the teacher or technician to confirm that they are working safely or that they are using materials properly.

Students should always be concerned for the quality of oral and written language, whether in an oral presentation, a lab report, a scientific article, a data sheet or an essay on the social impact of science and technology.

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*Each student is responsible for his or her own learning and must participate actively in competency development, using a variety of resources.*

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### Focus of the Competency

The field of science and technology is characterized by a rigorous approach to problem solving, among other things. The problems always involve initial information, a goal to be achieved and specifications describing the nature, meaning and scope of the problem. Seeking answers or solutions to scientific or technological problems involves using different types of reasoning and methodological procedures associated with science and technology (e.g. modelling, the observation, experimental and empirical methods, and technological design and analysis), which make use of strategies for exploring or analyzing and require creativity, a methodological approach and perseverance. Learning how to use these methods appropriately helps students gain a better understanding of the nature of scientific and technological activity.

Although they are based on systematic processes, these methods are not foolproof and may involve trial and error. To apply them, the students must be aware of their actions and be capable of reflecting on them, and ask questions for the purpose of validating the work in progress so that necessary adjustments can be made in accordance with the stated goals or the selected options. Since their results may raise new problems, achievements are always considered temporary and are a part of a continuous process of acquiring and expanding their knowledge.

As in Secondary Cycle One, a student who is able to find answers or solutions to scientific or technological problems can solve relatively complex problems requiring the application of a variety of methods. In Cycle One, a distinction is made between the experimental method and the technological design process: emphasis is placed on their specific characteristics, their distinct objectives and their complementary nature. In Cycle Two, the observation and empirical methods as well as modelling are added. The goal is to eventually combine these methods when seeking answers or solutions to scientific or technological problems.

Usually relatively complex, the initial problems are generally approached in a scientific manner. They raise a number of more specific questions and can be grouped together in subproblems according to their specific scientific principles or technological processes.

Finding answers or solutions to these two types of problems involves a **process that is dynamic and nonlinear**. This makes it necessary to move from one phase of the problem-solving process to another and to apply the appropriate methods, strategies, techniques, principles and concepts. If these

resources are to be used in combination, they must be adapted to the situation and its context.

The first step in solving a problem is to determine a way of representing it based on meaningful indicators and relevant elements. At first, this

representation can be rough and may require a number of adjustments throughout the process. New learning, the use of prior knowledge and information that has not yet been taken into account, discussions with peers or the teacher, and unexpected experimental results often lead to more refined reformulations that come closer to achieving the goal in question. The initial representation of a problem may therefore be modified over the course of the process. Sometimes, however, the initial representation needs little or no modification, if it is based on a solid foundation of knowledge.

The representation of the problem is used to explore various problem-solving scenarios in order to select the best option. This is followed by planning that takes into account material limitations and constraints and the availability of resources.

The students then follow the steps in the plan of action, taking care to record all observations that might prove useful later on. In addition, if they take measurements, they should take possible errors into account. New data can require a reformulation of the representation, adaptation of the plan of action or a search for a more appropriate solution.

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*The first competency focuses on the assimilation of concepts and strategies using a hands-on approach.*

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Analyzing results involves the organization, classification, comparison and interpretation of results obtained during the problem-solving process. It consists in identifying patterns and significant relationships in the results themselves and between the results and the initial data. This comparison makes it possible to formalize the problem and to validate or invalidate hypotheses and draw conclusions.

In order to ensure better use of methods and strategies, students should systematically review what they have done throughout the problem-solving process. This metacognitive task should also apply to the conceptual and technical resources used and their adaptation to the requirements of the different contexts.

Most of the methods used in the development of this competency must be applied in the lab or workshop. Students should follow instructions and demonstrate rigour and concern for effectiveness and efficiency. Safety should also be a constant concern.

This competency is inextricably linked to the other two and cannot be developed independently. The acquisition and use of specific knowledge is part and parcel of the process of finding answers and solutions to scientific and technological problems. Scientific and technological laws, principles and concepts are used to define a problem and formulate it in terms that approach an answer or solution. This competency cannot be developed without the mastery of communication strategies. The peer validation process is an inherent part of science and technology, as is the understanding and use of the language shared by members of the scientific and technological community.

## Key Features of Competency 1

### Defines a problem

Considers the context of the situation • Represents the problem  
• Identifies the initial data • Identifies the elements that seem relevant and the relationships between them • Reformulates the problem in terms of scientific and technological concepts • Proposes a possible explanation or solution

### Develops a plan of action

Explores some of the initial explanations or solutions  
• Chooses an explanation or solution • Identifies the necessary resources • Plans the steps involved in its implementation

## Seeks answers or solutions to scientific or technological problems

### Carries out the plan of action

Follows the steps in his/her plan • Uses the appropriate techniques and resources  
• Does tests, if applicable • Gathers all useful data and observations • If necessary, adjusts the plan of action or its implementation  
• Carries the plan of action through

### Analyzes his/her results

Looks for significant patterns or relationships • Judges the appropriateness of the answer or solution found • Makes connections between his/her results and scientific and technological concepts • Suggests improvements if necessary • Draws conclusions

## Evaluation Criteria

- Appropriate representation of the situation
- Development of a suitable plan of action for the situation
- Appropriate implementation of the plan of action
- Development of relevant conclusions, explanations or solutions

In order to evaluate the level of competency development achieved by the student, the teacher records a sufficient amount of evidence and makes an assessment based on the scales of competency levels for science and technology established by the Ministère de l'Éducation, du Loisir et du Sport (MELS).

## End-of-Program Outcomes

By the end of these programs, students are able to apply a problem-solving process. They start by defining the goal to be achieved or the need to be identified, as well as the conditions involved. They reformulate the problem using scientific and technological concepts. They come up with realistic hypotheses or possible solutions that they can justify.

They develop their plan of action by selecting methods in order to achieve their goal. They carefully control important variables. In the development of their plan of action, they select the relevant conceptual tools and materials.

They apply their plan of action in a safe manner and make any necessary adjustments. They collect data by correctly using the selected equipment. They take the precision of the tools and equipment into account. They always consider the possibility of measurement errors. In science, they analyze the data collected, using it to formulate relevant conclusions or explanations. If necessary, they propose new hypotheses, improvements to their solution, or new solutions. In technology, they test their solution to make sure that it meets the need identified or the requirements in the specifications. If necessary, they use information and communications technologies.

Throughout the process, they demonstrate rigour and refer systematically to the qualitative explanations and the mathematical formalism required to support their reasoning.

## COMPETENCY 2 Makes the most of his/her knowledge of science and technology

### Focus of the Competency

Science and technology affect our lives. In some ways, they have helped significantly improve our quality of life but, in other ways, they have given rise to ethical issues, and we must decide where we stand in relation to these questions. Every facet of human activity, be it personal, social or work-related, is influenced by science and technology to varying degrees. Their impact is so profound that they now appear to be indispensable tools for understanding and adapting to the world in which we live. To be able to function in society and fulfill our role as well-informed citizens, we must acquire scientific and technological literacy, which involves the ability to make the most of our knowledge of science and technology in various situations.

In Cycle One, students learned to apply their scientific and technological knowledge by attempting to identify the consequences of science and technology and to understand natural phenomena and the inner workings of certain technical objects. In Cycle Two, they must continue to do so in more complex situations. Students are called upon to examine a variety of issues and to form an opinion that takes into account different perspectives (e.g. aspects, points of view, consequences). Moreover, they are called upon to use previously acquired conceptual resources and to develop new ones.

In Cycle Two, students must put the issues in context. This means that they must construct a systemic representation of the issues, taking into account their different aspects (e.g. social, historical, economic) and various points of view (e.g. those of environmentalists, unions, politicians). This analysis also allows the students to identify the ethical questions at stake, envison solutions and examine their short- and long-term consequences.

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*This competency requires that students put an issue in context, identify the related scientific and technological principles, and form an opinion.*

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The ability to analyze an issue involves identifying related scientific principles. This competency is therefore based on the assumption that the students have assimilated the basic concepts needed to understand these principles. This understanding, however, is not limited to the mastery of mathematical formalism or the application of formulas. To understand a principle or a phenomenon, we must first represent it qualitatively, and sometimes quantitatively, explaining it using the appropriate laws and models, describing it, understanding the relationships involved and, sometimes, predicting new phenomena. Modelling and the empirical and observation methods are some of the resources students can use to gain a better understanding of scientific principles.

Making the most of one's scientific and technological knowledge often involves analyzing related objects, systems, products or processes. This analysis begins with an understanding of the overall function of the object, system, product or process. Then it is necessary to understand the operation of each component, its technical characteristics and the underlying scientific principles. Lastly, it involves considering solutions for constructing the object, system, product or process.

Making the most of one's scientific and technological knowledge also involves exercising critical judgment. The systematic analysis of an issue should allow students to gradually form an opinion. Having consulted different resources addressing different aspects and points of view, they can now organize their information and select the items on which their opinion will be based. They will then be able to justify or qualify their opinion on the basis of any new information obtained.

In order to ensure better use of methods and strategies, students should systematically review what they have done throughout the problem-solving process. This metacognitive task should also apply to the conceptual and technical resources used and their adaptation to the requirements of the different contexts.

Lastly, this competency could not be developed without using the communication skills needed to produce, interpret and share scientific and technological messages, and the appropriate scientific and technological language.

## Key Features of Competency 2

### **Puts scientific or technological issues in context**

Identifies aspects of the context (e.g. social, environmental, historical) • Makes connections between these aspects

- Identifies any ethical questions related to the issue
- Foresees long-term consequences

### **Understands the scientific principles underlying the issue**

Recognizes scientific principles • Describes them qualitatively or quantitatively • Makes connections between the principles using concepts, laws or models

### **Makes the most of his/her knowledge of science and technology**

### **Understands the technological principles underlying the issue**

Identifies the overall function of an object, system, product or process

- Identifies the different components and determines their respective functions
- Describes the principles underlying the construction and operation of the object, system, product or process
- Makes connections between the principles using concepts, laws or models
- Makes a schematic representation of the principles underlying the construction and operation of the object, system, product or process

### **Forms an opinion about the issue**

Seeks different resources and considers different points of view

- Determines the elements that can help form an opinion
- Supports his/her opinion with the elements considered
- Qualifies his/her opinion, taking others' opinions into account

## End-of-Program Outcomes

By the end of these programs, students are capable of dealing with situations and questions relating to current events and the major issues of the day, and analyzing them from the point of view of science and technology. They define the issue, explore its different aspects (e.g. social, environmental, economic, political, technological) and identify any ethical questions at stake. When necessary, they are able to evaluate the long-term consequences of the issues raised.

When students analyze a problem from a scientific point of view, they attempt to recognize the underlying principles. They propose explanations or tentative solutions and validate them using the relevant concepts, laws, theories and models. They can describe these scientific principles in qualitative terms and, when necessary, use mathematical formalism to justify their explanation. Students in the optional program must use mathematical formalism where required.

When students analyze a problem from a technological point of view, they determine the overall function of the object, technological system or product. They examine it in order to observe its main components. They handle the object or system and, if necessary, take it apart to understand its main subsystems and mechanisms. Students in the optional program are able to qualitatively describe its operating principles using relevant concepts, laws and models. They explain the solutions they chose for designing or making the technical object or technological system, using mathematical formalism where possible.

After exploring different aspects (e.g. social, environmental, economic, political, technological) or different ethical questions related to the issue, the students seek resources expressing different points of view. They give priority to information they deem important, paying special attention to the reliability of their sources. Thus, they form an informed opinion based among other things on scientific and technological principles. They are capable of justifying their opinion and reconsidering it in the light of new information. Students in the optional program must justify their opinion using well-developed arguments.

## Evaluation Criteria

- Formulation of appropriate questions
- Appropriate use of scientific and technological concepts, laws, models and theories
- Relevant explanations or solutions
- Suitable justification of explanations, solutions, decisions or opinions

In order to evaluate the level of competency development achieved by the student, the teacher records a sufficient amount of evidence and makes an assessment based on the scales of competency levels for science and technology established by MELS.

### Focus of the Competency

Communication plays an essential role in the construction of scientific and technological knowledge. To the extent that such knowledge is developed and instituted socially, a set of common meanings is required so that people can exchange ideas and negotiate points of view. This calls for a standardized language, i.e. a code that defines linguistic and graphical signs in accordance with the way they are used in the scientific and technological community. The dissemination of knowledge is also governed by certain rules. For example, research results must be validated by means of a peer review process before they are made public. Information can be communicated in different ways depending on whether it is meant for an audience of experts or nonexperts.

As in Secondary Cycle One, students must be capable of communicating in the languages used in science and technology and using the standards and conventions associated with these fields in order to participate in exchanges on scientific or technological issues, or to interpret or produce scientific or technological information. They must also learn to respect the intellectual property rights of the people whose ideas and results they borrow. Although interpretation is particularly important, participation in exchanges and the production of messages also play an important role.

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*This competency is developed in situations in which students participate in exchanges of information, and in the interpretation and production of scientific or technological messages.*

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This competency is developed in situations in which students participate in the exchange of scientific or technological information, whether they are sharing the results of their work with peers, consulting experts to find answers to certain questions, participating in activities involving the analysis or design of objects, systems or products, presenting a project, or producing a data sheet. These situations are particularly useful to students learning to refine their presentations or to validate a point of view by comparing it with others; they must also help students develop an open-minded and receptive attitude toward the diversity of knowledge, points of view and approaches. The fact that the everyday meaning of a term is sometimes different from its meaning

in scientific or technological language deserves special attention. Similarly, the meaning of concepts can differ depending on the context in which they are used. It is therefore essential that students take into account the context of the communication situation in order to determine the issues under debate and to adapt their behaviour accordingly.

Interpretation, another important feature of the competency, is involved in reading scientific or technical articles, listening to oral presentations, understanding lab reports, and using specifications, technical manuals and drawings. All of these activities require that the students understand the precise meaning of words, definitions, statements, graphs, diagrams and detail drawings. They must also make explicit connections between concepts and their various graphic or symbolic representations. When consulting documents or listening to presentations, students must verify the reliability of these sources and select the appropriate information.

Producing scientific or technological messages is also an important aspect of this competency, since the situations may require that students develop a research procedure, write a lab report, prepare a technical manual, design a prototype, summarize an article, make a detail drawing of a part or give a presentation on a scientific or technological topic. The target audience must be taken into account in order to determine the context of the message, that is, the appropriate level of complexity, structure and means of presentation. The proper use of concepts, formalisms, symbols, graphs, diagrams and drawings also adds to the clarity, coherence and precision of the message. Information and communications technologies can be exceptionally useful and enriching in this type of communication.

In order to ensure better use of production and interpretation strategies, students should review what they have done throughout their participation in the exchange. This metacognitive task should also apply to the conceptual and technical resources associated with communication, and their use and adaptation to the requirements of the different contexts.

This competency cannot be developed in isolation from the other two competencies in the program, and it contributes to their development and scope. It is enriched by the increased understanding resulting from the associated research and productions. The first competency, which focuses on scientific or technological problem solving, involves following certain standards and conventions, whether in developing a research procedure or production scenario, in explaining laws and principles, or in presenting the results of an experiment. Tables, symbols, graphs, diagrams, detail and assembly drawings, mathematical equations and models can all be used to present information, but it is important to use them in accordance with the rules specific to the fields of science, technology and mathematics.

The scientific and technological concepts involved in the second competency cannot be learned or used in isolation from a language and a certain type of discourse. For example, scientific laws are a way of modelling phenomena and are usually expressed through definitions or mathematical formalism. Understanding these laws means being able to associate them with the phenomena they represent.

## Key Features of Competency 3

### **Participates in exchanging scientific and technological information**

Is open to other points of view • Validates his/her point of view or solution by comparing it with others • Integrates appropriate scientific and technological terms into his/her oral and written vocabulary

### **Interprets scientific and technological messages**

Makes sure the sources are reliable • Identifies relevant information • Understands the precise meaning of words, definitions and statements • Makes connections between concepts and their various graphic or symbolic representations • Selects the significant elements

### **Communicates in the languages used in science and technology**

### **Produces and shares scientific and technological messages**

Takes the target audience and context into account • Structures his/her message • Uses the appropriate types of language in accordance with established standards and conventions • Uses the appropriate forms of presentation • Demonstrates rigour and coherence

## Evaluation Criteria

- Accurate interpretation of scientific and technological messages
- Appropriate production or sharing of scientific and technological messages
- Use of appropriate scientific and technological terminology, rules and conventions

In order to evaluate the level of competency development achieved by the student, the teacher records a sufficient amount of evidence and makes an assessment based on the scales of competency levels for science and technology established by MELS.

## End-of-Program Outcomes

By the end of these programs, students can interpret and produce oral, written or visual messages relating to science and technology.

When interpreting messages, they use the languages associated with science and technology. They correctly use scientific, technological, mathematical, symbolic and everyday language depending on the situation. They take the reliability of their sources into account. If necessary, they define the words, concepts and expressions used by referring to reliable sources. They review all the information consulted and then identify and use the elements they deem relevant and necessary for an accurate interpretation of the message.

They produce clear, well-structured and well-worded messages and follow conventions, while using the appropriate types of representation. They select and adequately use tools such as information and communications technologies, which help them deliver their message. If necessary, they adapt their messages to their target audience. Using everyday language, they are able to explain the messages they have produced or interpreted. When necessary, they compare their ideas with those of others. They defend their ideas, but adjust them when other people's arguments can help fine-tune their thinking. They always respect intellectual property rights in producing their messages.

## Program Content: Constructing and Using Resources

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The science and technology programs are intended to help students consolidate and enrich their scientific and technological literacy. They are also intended to make students aware of the importance of considering the short-, medium- and long-term environmental impact of science and technology and to prepare some of them for careers in which they will monitor and assess this impact in their community.

The optional Environmental Science and Technology program uses the same resources as the compulsory Science and Technology program. However, it addresses additional concepts and resources. Their assimilation qualifies students in the General Education Path to take the optional programs offered in Secondary V.

The resources constructed in the optional program, along with those in the basic program, provide for a more in-depth look at the concepts involved in the environmental issues described in Appendix A. In addition to the issues suggested in the basic program, i.e. climate change, the energy challenge, drinking water and deforestation, the optional program includes the issues of energy,<sup>14</sup> residual materials and food production. These issues are conducive to the development of the program's three competencies, as well as the assimilation of the related concepts.

The resources section is divided into two parts. The first part presents the compulsory concepts. The second part addresses methods, strategies, attitudes and techniques. Methods are essentially ways of doing things in a problem-solving approach to science and technology. Strategies are used to apply competencies with a view to combining different methods. Attitudes related to knowledge or skills engage the students' responsibility. Finally, techniques are methodical procedures often used in science and technology. They play an essential role in competency development.

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14. In this optional program, the study of energy is a continuation of the study of the energy challenge presented in the second year of the Science and Technology program.

### Compulsory concepts

The compulsory concepts are divided into four areas: The Living World, The Material World, The Earth and Space, and The Technological World. Since these areas are interrelated, they should not be addressed separately or sequentially. The same applies to the concepts, which should not be covered in a predetermined chronological order, but through integrated learning and evaluation situations.

Each of the four areas is presented in a two-column table. The first column lists the general concepts and orientations, which specify and contextualize the conceptual foundations, while giving teachers a certain amount of latitude. Occasionally, additional notes provide information about the scope of the concepts under study and the limits of the intervention. The second column lists the compulsory concepts, but teachers should in no way feel bound by this list. The learning and evaluation situations should in fact be designed to go beyond these minimum requirements.

A table of cultural references is presented at the end of the introduction to each area. These references can enrich learning and evaluation situations and contribute to the development of integrative educational activities that reflect the students' social, cultural and everyday reality. They can also be related to the broad areas of learning and other subjects.

The section ends with a summary table of all the compulsory concepts in the programs.

## The Living World

The environmental topics proposed in these programs can be studied using five ecological concepts and the basic concepts of Mendelian genetics. A grasp of the concepts of population, dynamics of communities, dynamics of ecosystems, ecological footprint and ecotoxicology enables students to understand the levels of organization of living organisms, their relationship

with the environment and the effects of human activity on these organisms. Familiarity with the basic concepts of Mendelian genetics is essential for understanding conservation and biodiversity challenges and the issues related to our ability to modify the very nature of the living organisms around us.

Orientations	Compulsory Concepts
<p><b>Ecology</b></p> <p>When several individuals of a single species occupy the same territory, they form a population. The density of organisms and their distribution are the main characteristics of populations. The influence of abiotic and biotic factors is an essential aspect of the study of population dynamics. Many of these factors, such as natality, mortality, immigration and emigration, play an important role in the biological cycle of these populations. Reproduction and survival are closely linked to the accessibility of resources.</p> <p>Populations are never alone in their territory. Several types of biotic interactions occur between these populations, which constitute a community. Each community is characterized by a trophic structure and a relative abundance of constituent species (biodiversity). The trophic structure, in which organisms interact and form food webs, is an important concept for explaining the dynamics of communities. These food webs are influenced by the nutrients available at the bottom of the food chain and by the major predators at the top. Modifications in the structure and composition of communities occur when disturbances cause an imbalance. At that point, a series of changes gradually takes place in order to re-establish a balance in the community: this is referred to as ecological succession. Human activity and natural disasters are the main causes of disturbance in communities.</p> <p>Another factor can also play an important role in the disturbance of community relations: the presence of pathogenic microorganisms in the environment (bacteria, viruses, fungi, parasites). Some of these agents can be allergenic, toxic or even deadly in some cases.</p> <p>Ecosystems are all characterized by the relationships between the organisms in a community and abiotic factors. Autotrophic organisms introduce energy into the ecosystem, where it becomes organic matter. This primary productivity (biomass) influences the total amount of energy in the ecosystem. Solar energy is converted into chemical energy, transmitted from one trophic level to the other through the food chain and dissipated in the form of heat. At every trophic level, biological and geological processes return various nutrients to the environment. This is referred to as chemical recycling. Microorganisms and decomposers play an essential role in the process of organic decomposition, which allows various inorganic elements to reenter circulation.</p> <p>Climate change and the energy challenge are particularly useful in understanding energy circulation and recycling in ecosystems.</p> <p><u>The ecological footprint is a tool for evaluating the actual impact of human activity on ecosystems, in order to provide for the balanced management of resources. It corresponds to the biologically productive surface of the Earth necessary to ensure the standard of living of an individual or a population and the elimination of the associated waste.</u></p>	<ul style="list-style-type: none"> <li>– Study of populations (density, biological cycles)</li> <li>– Dynamics of communities               <ul style="list-style-type: none"> <li>• Biodiversity</li> <li>• Disturbances</li> </ul> </li> <li>– Dynamics of ecosystems               <ul style="list-style-type: none"> <li>• Trophic relationships</li> <li>• Primary productivity</li> <li>• Material and energy flow</li> <li>• Chemical recycling</li> </ul> </li> <li>– <u>Ecological footprint</u></li> <li>– <u>Ecotoxicology</u> <ul style="list-style-type: none"> <li>• <u>Contaminants</u></li> <li>• <u>Bioconcentration</u></li> <li>• <u>Bioaccumulation</u></li> <li>• <u>Toxicity threshold</u></li> </ul> </li> </ul>

## The Living World (Cont.)

Orientations	Compulsory Concepts
<p>Ecotoxicology is the study of the long-term effects of certain chronic pollutants on ecosystems. While some contaminants may degrade naturally, others (e.g. phosphates and mercury) accumulate in ecosystems, living organisms, waterways, lakes and ponds. Prolonged exposure of a food web to toxic substances helps explain why such pollutants can appear in aquatic organisms at concentrations higher than those measured in the surrounding waters.</p> <p>The toxicity of each contaminant depends on its concentration, the characteristics of the environment in which it is released, the nature of the organisms with which it comes into contact and the duration of exposure. Data are available to assess the effects of a pollutant on organisms, including the toxicity threshold, defined as the minimum quantity of contaminant (in milligrams per kilogram of the organism’s mass) that will produce a harmful effect on an organism.</p> <p><b>Note:</b> In the optional program, students are only required to perform a qualitative analysis of the toxicity of the environment being studied, based on data made available to them.</p>	
<p><b>Genetics</b></p> <p>Plant and animal cross-breeding can foster the emergence of a useful trait in the majority of individuals in a species. By adding or modifying genes, genetic engineering can induce the loss or creation of characteristics in the first generation of plants and animals. Genes, the building blocks of heredity, control the transmission of specific character traits. Each gene in a eukaryotic cell is made up of two alleles, which can exist in a number of variations. There is no guarantee that a gene will be transmitted, or expressed. For example, when parents provide two identical alleles of a given gene, the offspring is homozygotic for this gene and the trait borne by the alleles is expressed. If, however, the offspring possesses two different alleles, it is heterozygotic for the gene in question and a number of possibilities exist, including dominance, which is observed when a dominant allele is expressed to the detriment of the recessive allele. This implies that, by modifying the genotype of a living organism, we can modify its observable anatomical, morphological and physiological characteristics, or its phenotype.</p> <p>Moreover, an individual’s genetic code contains instructions for synthesizing the proteins required for the organism to function optimally. Each gene, or DNA segment, contains instructions for the production of a specific polypeptide chain. The transcription of DNA into messenger RNA occurs in the nucleus, while the transformation into an amino acid chain with the help of transfer RNA takes place on a ribosome in the cytoplasm. The integrity of the DNA molecules and these processes is necessary for a healthy organism, as the slightest error could cause the formation of an inappropriate protein and have negative physiological effects. Certain substances in the environment have a cellular effect that can deregulate protein synthesis or modify DNA molecules.</p> <p><b>Note:</b> This program, like the Science and Technology program for the first year of Cycle Two, contains concepts of biotechnology in The Technological World.</p>	<ul style="list-style-type: none"> <li>– Heredity</li> <li>– Gene</li> <li>– Allele</li> <li>– Character trait</li> <li>– Genotype and phenotype</li> <li>– Homozygote and heterozygote</li> <li>– Dominance and recessivity</li> <li>– Protein synthesis</li> <li>– Cross-breeding</li> </ul>

Cultural References			
History	Community resources	Applications	Events
Charles Darwin Alfred Wallace Hermann Müller Alfred Hershey Martha Chase René Truhaut Mathis Wackernagel William Rees	Protected areas Zoos UNESCO world reserves Environmental groups Museums of science and technology Conservation agencies Research chairs, centres and institutes involved in environmental education Environment Canada's Biosphere Regional environmental councils	Depollution activities Environmental protection Sustainable development	Discovery of the structure of DNA Earth Summits Kyoto Protocol World Water Forum

## The Material World

The compulsory concepts for The Material World are organized around seven general concepts: the physical properties of solutions, chemical changes, the organization of matter, the periodic table, nuclear transformations, electricity

and electromagnetism, and transformations of mechanical energy. These concepts have been chosen for their importance in the study of various environmental issues.

Orientations	Compulsory Concepts
<p><b>Physical properties of solutions</b></p> <p>In our environment, matter usually occurs in the form of mixtures, many of which are aqueous solutions. The fact that many substances dissolve in water is essential to understanding biological and environmental phenomena. Special attention will be given to the properties of acidic, basic and salt aqueous solutions. These solutions are defined on the basis of their measurable and observable properties.</p> <p>The physical properties of aqueous solutions vary depending on the nature and proportion of their constituents. The solubility of a solid or gas is measured in grams of solute per volume of solvent and varies according to temperature. Concentration is expressed in parts per million (ppm), as a percentage, in grams or in moles of solute per litre of solution. In the natural water cycle, dissolution, dilution and evaporation cause variations in the concentration of dissolved substances.</p> <p>Some substances dissolved in water conduct electricity. They are called electrolytes and are referred to as strong or weak depending on their ability to conduct electricity when dissolved in water. The physical change that occurs when a substance is dissolved in water and the ability of electrolyte solutions to conduct electricity can be explained in part by the dissociation of electrolyte molecules into ions.</p>	<ul style="list-style-type: none"> <li>– Concentration (ppm, <u>mole/L</u>)</li> <li>– Electrolytes</li> <li>– <u>Strength of electrolytes</u></li> <li>– pH scale</li> <li>– Electrolytic dissociation</li> <li>– Ions</li> <li>– Electrical conductivity</li> </ul>
<p><b>Chemical changes</b></p> <p>The chemical properties of a substance or group of substances are based on the chemical changes that occur when they come into contact with each other. Since the products are different from the reagents, they are characterized by different properties. The number of atoms of each element and their mass, however, remain the same. This makes it possible to balance chemical equations. <u>The quantities of matter that are involved in a chemical reaction are calculated (in moles and grams). They make it possible to estimate the amount of energy produced or absorbed.</u></p> <p>Several chemical reactions related to each of the topics will be studied. They show that the atoms of different elements and ions have the ability to bond with other atoms depending on their atomic structure. <u>The tendency of atoms to acquire the peripheral electronic structure of the neighbouring inert gas, through the loss, gain or sharing of electrons, is determined by the number and arrangement of the electrons in the atoms.</u></p> <p><b>Note:</b> <u>Stoichiometric calculations are based on the assumption that the chemical reactions are complete. Transition elements are not considered in the study of the different types of bonds.</u></p>	<ul style="list-style-type: none"> <li>– Combustion</li> <li>– <u>Oxidation</u></li> <li>– Photosynthesis and respiration</li> <li>– Acid-base neutralization reaction</li> <li>– <u>Salts</u></li> <li>– Balancing chemical equations</li> <li>– Law of conservation of mass</li> <li>– <u>Stoichiometry</u></li> <li>– <u>Types of bonds</u> <ul style="list-style-type: none"> <li>• <u>Covalent</u></li> <li>• <u>Ionic</u></li> </ul> </li> <li>– <u>Endothermic and exothermic reactions</u></li> </ul>

Orientations	Compulsory Concepts
<p><b>Organization of matter</b></p> <p>Throughout history, different models of the structure of matter have been developed to explain its properties and the changes it undergoes. In studying the Rutherford-Bohr atomic model, students learn that there are two types of particles (protons and electrons), which are organized in a particular fashion. The nucleus is made up, among other things, of protons. The number of electrons is equal to the number of protons. The electrons travel in orbits around the nucleus in electron shells that correspond to different energy levels. <u>The simplified atomic model integrates a second nuclear particle (the neutron), whose existence has been confirmed, and includes all three types of particles.</u></p> <p><u>Matter is also organized at a molecular and ionic level. The nomenclature and notation of the formulas of various compounds, including those made up of the most common polyatomic ions, are based on accepted rules.</u></p> <p><u>The concept of mole and Avogadro's number are addressed to enable students to calculate the quantitative relationships between reagents and products in chemical reactions.</u></p>	<ul style="list-style-type: none"> <li>– Rutherford-Bohr atomic model</li> <li>– Lewis notation</li> <li>– <u>Simplified atomic model</u></li> <li>– <u>Neutron</u></li> <li>– <u>Nomenclature and notation rules</u></li> <li>– <u>Polyatomic ions</u></li> <li>– <u>Concept of mole</u></li> <li>– <u>Avogadro's number</u></li> </ul>
<p><b>The periodic table</b></p> <p>The periodic table of the elements provides a wealth of information, some of which is used to explain the properties of metals, nonmetals and metalloids, and to predict behaviours by relating the atomic structure, the properties of elements and the type of bond between the atoms.</p> <p><u>The elements are classified in increasing order by atomic number. This number designates the number of protons in the nucleus and makes it possible to differentiate among the elements. This classification (with a few irregularities) is based on atomic mass, the relationships between elements with similar chemical properties and the periodicity of certain physical and chemical properties of the elements.</u></p> <p><u>Some atoms in a given element, called isotopes, differ from the others in the number of neutrons they have and, therefore, in their atomic mass. They occupy the same place in the periodic table because they have the same atomic number and the same chemical properties. Isotopes are naturally occurring, but they can also be produced in the laboratory or in industrial settings.</u></p>	<ul style="list-style-type: none"> <li>– Families and periods</li> <li>– <u>Relative atomic mass</u></li> <li>– <u>Atomic number</u></li> <li>– <u>Periodicity of properties</u></li> <li>– <u>Isotopes</u></li> </ul>
<p><b>Nuclear transformations</b></p> <p><u>Transformations of matter are considered "nuclear" when they occur in the nucleus of the atom. During these transformations, the cohesive strength of the nucleons is insufficient to maintain the stability of the nucleus. New nuclei are created (heavier in the case of fusion and lighter in the case of fission), particles travel at great speed (kinetic energy) and vast quantities of energy are emitted in the form of radiation.</u></p> <p><u>Nuclear energy has enormous potential. However, while the use of radioactive substances has undeniable advantages, it has a definite impact on the environment.</u></p>	<ul style="list-style-type: none"> <li>– <u>Nuclear stability</u></li> <li>– <u>Radioactivity</u></li> <li>– <u>Fission and fusion</u></li> </ul>

## The Material World (Cont.)

Orientations	Compulsory Concepts
<p><b>Electricity</b></p> <p>The study of matter would be incomplete without an exploration of its electrical properties. Electrical charges can appear on certain neutral materials after they are rubbed with other materials. These charges attract when they are of opposite signs and repel when they are of the same sign. <u>The force of attraction or repulsion is directly proportional to the product of two charges and inversely proportional to the square of the distance between them.</u> <u>The intensity of the electrical field produced by a charge at a given point is directly proportional to the charge and inversely proportional to the square of the distance between the point and the charge.</u> The appearance of electrical charges can be explained by the mobility of negative charges (electrons) and their accumulation on the surface of certain substances. The affinity of different materials for electrons helps explain a number of everyday electrical phenomena.</p> <p>Some elements and materials are good conductors of electricity. They are used to allow electrons to move through electrical circuits. Electrical circuits can be made up of various elements connected in series or in parallel. Ohm's law establishes the relationship between the voltage, resistance and intensity of the current in a circuit. Each of these has its own unit of measurement. <u>Kirchhoff's and Ohm's laws enable us to determine the intensity and voltage at the terminals of the different elements of a circuit. Indirectly, they make it possible to calculate the equivalent resistances of a circuit.</u></p> <p>Certain elements of a circuit also transform part of the electrical energy into another form of energy. Relationships are established between the consumption of electrical energy and voltage, current intensity and time. The electrical power of a device is determined by how much energy it consumes in a given unit of time. Each element has its own unit of measurement.</p> <p><b>Note:</b> Students are not required to work on series-parallel circuits. <u>Coulomb's law is studied qualitatively and quantitatively.</u> Electrical force is measured between two charges.</p>	<ul style="list-style-type: none"> <li>– Electrical charge</li> <li>– Static electricity</li> <li>– Ohm's law</li> <li>– Electrical circuits</li> <li>– Kirchhoff's laws</li> <li>– Relationship between power and electrical energy</li> <li>– <u>Electrical field</u></li> <li>– <u>Coulomb's law</u></li> </ul>
<p><b>Electromagnetism</b></p> <p>Matter can also be characterized by its magnetic properties. Some materials have the property of creating a magnetic field. Similar poles repel, while opposite poles attract.</p> <p>An electrical current can also create a magnetic field, <u>regardless of whether the wire is straight or coiled.</u> Conventionally speaking, the lines of the magnetic field created by a natural or artificial magnet are determined by the orientation (direction) of the North pole of the needle of a compass in the same field. The direction of magnetic field lines can be determined rapidly by applying the right-hand or left-hand rule, depending on whether the aim is to determine the conventional direction of the current or the actual direction in which the electrons are moving.</p> <p><b>Note:</b> Only the qualitative aspects of electromagnetism are considered.</p>	<ul style="list-style-type: none"> <li>– Forces of attraction and repulsion</li> <li>– Magnetic field of a live wire</li> <li>– <u>Magnetic field of a solenoid</u></li> </ul>

Orientations		Compulsory Concepts	
<p><b>Transformation of mechanical energy</b></p> <p>Energy occurs in a number of forms in the environment, but it always corresponds to the amount of work a system is likely to produce. Work involves force and motion. The relationship between work, force and travel will be studied based on whether or not the application point of the force is travelling in the same direction as the force.</p> <p>Using the appropriate methods, it is possible to convert one form of energy into another. In an isolated system, the total amount of energy is maintained during these changes. If the system is not isolated, it will lose a certain amount of energy, which is absorbed by the environment and neighbouring systems. The amount of energy transformed corresponds to the amount of work provided. Transformations of kinetic energy to potential energy, and vice versa, are considered.</p> <p>A warm body exhibits a characteristic behaviour: as it cools, it warms cooler bodies with which it is in contact. Although “heat” and “temperature” are often used to mean the same thing in everyday language, students must make a clear distinction between the two, especially when they are studying climate change. The relationship between the quantity of heat energy, specific heat capacity, mass and temperature variations will be examined.</p> <p><b>Note:</b> The qualitative and quantitative aspects of the transformation of energy are addressed.</p>		<ul style="list-style-type: none"> <li>– Law of conservation of energy</li> <li>– Energy efficiency</li> <li>– Distinction between heat and temperature</li> <li>– <u>Relationship between work, force and travel</u></li> <li>– <u>Relationship between mass and weight</u></li> <li>– <u>Effective force</u></li> <li>– <u>Relationship between work and energy</u></li> <li>– <u>Relationship between potential energy, mass, acceleration and travel</u></li> <li>– <u>Relationship between kinetic energy, mass and velocity</u></li> <li>– <u>Relationship between heat energy, specific heat capacity, mass and temperature variations</u></li> </ul>	
Cultural References			
History	Community resources	Applications	Events
<p>Svante Arrhenius</p> <p>Thomas Edison</p> <p>Blaise Pascal</p> <p>Isaac Newton</p> <p>Hans Oersted</p> <p>Joseph Henry</p> <p>Michael Faraday</p> <p>James Watt</p> <p>Ernest Rutherford</p> <p>Niels Bohr</p> <p>Gilbert Lewis</p> <p>Wilhelm Homberg</p> <p>Germain Hess</p> <p>James Chadwick</p> <p>Amedeo Avogadro</p> <p>Joseph John Thomson</p> <p>Julius von Mayer</p>	<p>Faculties of science and engineering</p> <p>Museums of science and technology</p> <p><u>Environmental groups</u></p> <p><u>Geological Survey of Canada</u></p> <p><u>Agence de l’efficacité énergétique du Québec</u></p>	<p>Means of transportation</p> <p>Water purification systems</p> <p>Development of the electrical network</p>	<p><u>Construction of hydroelectric developments</u></p> <p><u>Construction of wind farms</u></p>

## The Earth and Space

In addition to providing an opportunity to study the interactions that occur in the biosphere, the concepts associated with The Earth and Space addressed in the optional program make it possible to closely examine the impact of human activity on ecosystems. Within limits, various biogeochemical cycles, such as the phosphorus cycle, ensure the survival of ecosystems. This

regulatory ability, however, is disrupted by human activity. Certain socioeconomic development models and methods used to implement them are having an unprecedented effect on certain biomes. Familiarity with the different systems enables us to better understand the balance of the geosphere. The concepts associated with space are addressed with respect to energy.

Orientations	Compulsory Concepts
<b>The Earth</b>	
<p><b>Biogeochemical cycles</b></p> <p>A biogeochemical cycle describes changes in an organic or mineral element in the biosphere. The carbon cycle is regulated by the interaction of continental plates, the atmosphere, the oceans and living organisms. Although plants use photosynthesis to fix carbon in nonvolatile forms, carbonate rock, precipitated or created by living beings, constitutes the largest reserve of CO<sub>2</sub>. While this gas is released during volcanic eruptions, anthropogenic emissions restore the natural balance. Certain environmental biotechnologies contribute to the chemical recycling of carbon.</p> <p>Although it is abundant, atmospheric nitrogen can be assimilated by plants only in the presence of certain bacteria. The metabolism of biological organisms—alive or dead—produces waste that returns nitrogen to its mineral state and the cycle begins anew. Significant variations in the humidity, temperature or pH of the soil affect the regulation of the nitrogen cycle. Plants are the only source of nitrogen usable by animals, which is a good reason for preserving the world’s plant life.</p> <p>Phosphorus occurs mainly in rocks and is introduced into biological systems through natural erosion processes. Decomposed biological waste can accumulate in large quantities in soil and sediment. Human activity interacts with each of these cycles by creating huge amounts of organic and mineral waste. The nitrogen and phosphorus cycles are affected by the use of fertilizers, as well as by household and industrial wastewater containing detergents and phosphates.</p>	<ul style="list-style-type: none"> <li>– Carbon cycle</li> <li>– Nitrogen cycle</li> <li>– <u>Phosphorus cycle</u></li> </ul>
<p><b>Climate zones</b></p> <p>The distribution of biomes is a function of geographic latitude and other factors such as altitude, temperature and soil type. Their composition varies, since habitat conditions influence the distribution of plant and animal species. Marine biomes are at the bottom of an immense food pyramid; their continued health is therefore critical for humans. The types of animals present in a terrestrial biome depend on the types of plants there. Any imbalance caused by habitat destruction or contamination will have an impact on the ecosystems and, eventually, on a wide range of human activity.</p>	<ul style="list-style-type: none"> <li>– Factors that influence the distribution of biomes</li> <li>– Marine biomes</li> <li>– Terrestrial biomes</li> </ul>

Orientations	Compulsory Concepts
<p><b>Lithosphere</b></p> <p>The lithosphere contains a wide variety of mineral resources essential to the development of civilization, including metals, industrial minerals and construction materials. The use and transformation of minerals, however, have an impact on the environment. In addition, minerals exist in limited amounts, hence the growing need to take another look at residual materials and recycling in general.</p> <p>The permafrost is sensitive to climate change because the underground ice it contains is unstable. Warming of the permafrost can cause landslides and damage to infrastructures, alter the landscape and ecosystems, <u>and give off methane.</u></p> <p>Fossil fuels are nonrenewable sources of energy, as are the radioactive materials used in nuclear power plants. The search for new energy sources and the use of renewable resources are two major concerns in today’s world.</p> <p>The layers we see in a core sample, called horizons, differ in structure and composition. Studying a soil profile helps us understand the circulation of chemical elements in the soil and predict how it will evolve. Humidity, pH and mineral content help regulate the biological activity of soils, which is essential for feeding living organisms. <u>Some agricultural and forestry practices reduce the soil’s ability to accommodate healthy vegetation. Overcutting exposes more soil to erosion and strips the topsoil of essential minerals and microorganisms.</u></p> <p><u>The buffering capacity of the soil is its ability to limit pH variations, which enables it to postpone the consequences of contamination. Its measurement is an indicator of the soil’s fertility.</u></p> <p><u>Contamination by persistent organic compounds or heavy metals can modify the physical, chemical and biological properties of the soil and affect its fertility. Soil pollution is also caused by atmospheric deposits due to industrial and agricultural activity. For example, the gradual acidification of the soil resulting from acid rain gradually reduces its buffering capacity and leads to the introduction of nutrients or heavy metals into the system.</u></p>	<ul style="list-style-type: none"> <li>– Minerals</li> <li>– Permafrost</li> <li>– Energy resources</li> <li>– Soil profile (horizons)</li> <li>– <u>Soil depletion</u></li> <li>– <u>Buffering capacity of the soil</u></li> <li>– <u>Contamination</u></li> </ul>

## The Earth and Space (Cont.)

Orientations	Compulsory Concepts
<p><b>Hydrosphere</b></p> <p>A catchment area is a territory bounded by crest lines (geomorphology) surrounding a waterway, into which flow ground and surface water. Human activity in a catchment area, for example the creation of a reservoir upstream from a hydroelectric power plant, can disturb ecosystems.</p> <p>Because of their ability to absorb heat, the oceans play an essential role in regulating climate by standardizing the temperature of the Earth. There are two types of marine currents, which are interrelated. Surface currents, generated by wind, ensure wide-scale horizontal circulation. Deep currents, caused by differences in temperature or salinity, ensure vertical circulation between the different layers of the ocean. These vertical currents are very sensitive to small local variations in temperature. The rise in sea level, due to the accelerated thawing of glaciers and ice floes, is a major concern for coastal populations.</p> <p>Marine currents and tides create large quantities of energy. Tidal power plants use tides to produce electrical energy.</p> <p><u>Lakes, waterways and wetlands are dynamic systems home to a variety of species whose development depends on factors such as the temperature, oxygenation and chemical composition of the water. Within limits, an ecosystem is capable of transforming biodegradable organic materials in order to maintain a certain balance. An aquatic environment becomes polluted once its balance has been permanently modified either by the introduction of vast quantities of toxic substances or by an increase in water temperature. When pollutants accumulate, they can cause a decline in populations of more fragile species, alter their physiological abilities or degrade the quality of the water to such an extent that it becomes unsafe for drinking. Other pollutants, such as plastics, metals and some pesticides, are not biodegradable, or barely so; these substances harm the organisms that ingest them. The effects of the different pollutants on aquatic environments depend on the nature and concentration of the pollutant, as well as on the characteristics of the ecosystem. An excessive concentration of phosphates or nitrates, for example, may result in the proliferation of cyanobacteria. In some cases, this can result in the production of neurotoxins harmful to living organisms.</u></p> <p><u>Eutrophication is a stage in the natural evolution of a body of water. The process intensifies in the presence of excessive amounts of nutrients, particularly nitrogen and phosphorus compounds, which accelerate the growth of algae and other plant forms. This increase in biomass, combined with high water temperatures, causes a decrease in the amount of dissolved oxygen and limits the self-cleaning ability of the body of water. This form of degradation is related to agricultural, household and industrial activities (e.g. animal waste, agricultural runoff, wastewater).</u></p>	<ul style="list-style-type: none"><li>– Catchment area</li><li>– Oceanic circulation</li><li>– Salinity</li><li>– Glacier and ice floe</li><li>– Energy resources</li><li>– <u>Contamination</u></li><li>– <u>Eutrophication</u></li></ul>

Orientations	Compulsory Concepts
<p><b>Atmosphere</b></p> <p>The Earth reflects part of the heat generated by solar radiation back into space. Some gases in the atmosphere absorb this heat and cause the temperature to rise: this is the greenhouse effect. Carbon dioxide is the most abundant greenhouse gas. Its proportion has increased over the past century because of the use of fossil fuels and the manufacture of cement. Methane and other gases also contribute to the greenhouse effect. <u>Also, prevailing winds foster the circulation of contaminants in the atmosphere. Thus a biome located far away from the emission of gases can become contaminated.</u></p> <p>The different types of air masses can be distinguished by their temperature and humidity. These masses circulate around the globe at the whim of wind, convection currents and the Earth’s rotational movement. Cloud systems result when air masses with different characteristics meet.</p> <p>A cyclone is a low-pressure area. Although any low-pressure area can be called a “cyclone,” the term often refers to a particular type of system (hurricane or typhoon) that forms over tropical seas and causes abundant precipitation accompanied by strong winds and generally devastating effects. Pressure variations caused by cyclones and anticyclones ensure atmospheric circulation.</p> <p>Wind is also a resource. Whether it be to move around, perform mechanical tasks or produce electrical energy, humans take advantage of wind energy by using sails and blades whose shapes, materials and dimensions vary depending on the application. Wind energy is an abundant source of soft energy.</p> <p><u>The different substances emitted during the combustion of fossil fuels have harmful effects at the local, regional and planetary levels. Oxides of sulphur, carbon and nitrogen are acid precursors; they contribute to the acidification of precipitation. The air can also be contaminated by solid and liquid suspended particulates (e.g. dust, pollen, soot, smoke, droplets) that affect the respiratory system.</u></p>	<ul style="list-style-type: none"> <li>– Greenhouse effect</li> <li>– Atmospheric circulation                         <ul style="list-style-type: none"> <li>• <u>Prevailing winds</u></li> </ul> </li> <li>– Air mass</li> <li>– Cyclone and anticyclone</li> <li>– Energy resources</li> <li>– <u>Contamination</u></li> </ul>
<b>Space</b>	
<p><b>Space</b></p> <p>The Sun emits a phenomenal amount of energy in every region of the electromagnetic spectrum. Humans have been using the Sun’s heat to meet their needs for a very long time. The photovoltaic sensors on solar panels transform radiation energy into electrical energy.</p> <p>The gravitational pull of the moon on the Earth’s large surfaces of water is in large part responsible for the tides. The energy of the tides is captured in tidal power plants. This is one of the means humans have of meeting their energy needs.</p>	<ul style="list-style-type: none"> <li>– Solar energy flow</li> <li>– Earth-Moon system (gravitational effect)</li> </ul>

The Earth and Space (Cont.)

Cultural References			
History	Community resources	Applications	Events
<p><u>Gro Harlem Brundtland</u></p>	<p>Geological Survey of Canada                      Agence de l'efficacité énergétique du Québec                      Natural Resources Canada                      Ouranos Consortium                      Greenpeace  <u>Environmental groups</u>  <u>Recyc-Québec</u>  <u>Environment Canada</u>  <u>Conservation agencies</u>  <u>Regional environmental councils</u></p>	<p>Observation satellites                      Global positioning systems  <u>Depollution activities</u>  <u>Environmental protection</u>  <u>Water purification systems</u>  <u>Sustainable development</u></p>	<p>Earth Summits                      Kyoto Protocol                      Meteorological phenomena  <u>Environmental disasters</u></p>

## The Technological World

Combining different knowledge related to the use, understanding and creation of technical objects and systems, the general concepts associated with The Technological World are related to graphical language, engineering, materials, manufacturing and biotechnology. Aspects of manufacturing are addressed in the section on techniques. Since the problems to be solved this year are more diverse and difficult, the concepts must be addressed in greater detail. Also, new aspects of mechanical linking and electricity, including typical components, and new materials such as plastics, ceramics and composites have been introduced in order to allow for a greater variety of possible solutions to a design or analysis problem.

Objects, systems, products and processes are also addressed. All of these are associated with the different environmental topics. They all involve specific knowledge and practices and reflect scientific, technical, social, environmental and ethical possibilities and constraints. The in-depth study of technological concepts and the associated achievements should help students gain a better understanding of objects, machines and systems in general, and those related to the environment in particular.

Orientations	Compulsory Concepts
<p><b><u>Graphical language</u></b>            Representing objects in exploded view enables us to easily visualize each component. The theory of orthogonal projection is used in detail drawings, assembly drawings and isometric representations. Assembly drawings represent the different parts of a technical object or system in their proper positions. This type of drawing makes it possible, before any manufacturing steps are taken, to validate technological solutions (e.g. assembly problems, overall dimensions, interference). Detail drawings are based on the assembly drawing and define each part. The imperfection of machines, measuring instruments and so on makes it necessary to set limits (error tolerance) within which a dimension must fall. In the case of a mechanism, for example, this makes it possible to replace defective parts with new ones (interchangeability).</p>	<ul style="list-style-type: none"> <li>– <u>Axonometric projection: exploded view (reading)</u></li> <li>– <u>Multiview orthogonal projection (assembly drawing)</u></li> <li>– <u>Dimensional tolerances</u></li> </ul>

## The Technological World (Cont.)

Orientations	Compulsory Concepts
<p><b>Engineering</b></p> <p>The design or analysis of a technical object or a system is based on fundamental concepts of mechanics and electricity and on design and analysis processes specific to the field of engineering.</p> <p>In mechanics, these concepts involve <u>the adhesion and linking of parts, the independent movement still possible when parts are mechanically linked</u>, the most common mechanical functions, and the transmission and transformation of motion, all of which are examined in detail. Formal study of these concepts enables students to consider solutions based on specific types of links, guiding controls and mechanisms that allow for rotational or translational motion.</p> <p>In electricity, the compulsory concepts are related to the different electrical components and their function (power supply, conduction, insulation, protection, control and transformation). A close study of these components enables students to select and combine them appropriately.</p> <p>In the design and analysis of an object or system, such technical knowledge makes it possible to determine or justify the use of different shapes and materials, to apply or explain operating principles and to use or suggest construction solutions.</p> <p>Many objects, systems and types of equipment related to the environment fall into this category (e.g. rain gauge, turbine, pump).</p> <p><b>Note:</b> The study of the operating principles of various electrical components per se is not required.</p>	<p><b>Mechanics</b></p> <ul style="list-style-type: none"><li>– Characteristics of the linking of mechanical parts</li><li>– <u>Adhesion and friction between the parts</u></li><li>– <u>Degrees of freedom of a part</u></li><li>– Guiding controls</li><li>– Construction and characteristics of motion transformation systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)</li><li>– Speed changes</li><li>– Construction and characteristics of motion transformation system (screw gear system, cams, <u>eccentrics</u>, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)</li></ul> <p><b>Electricity</b></p> <ul style="list-style-type: none"><li>– Power supply</li><li>– Conduction, insulation and protection (<u>resistance and coding, printed circuit</u>)</li><li>– Typical control functions (<u>lever, pushbutton, toggle, unipolar, bipolar, unidirectional, bidirectional</u>)</li><li>– Transformation of energy (electricity and light, heat, vibration, magnetism)</li><li>– <u>Other functions (condenser, diode)</u></li></ul>

Orientations	Compulsory Concepts
<p><b>Materials</b></p> <p>The discovery that it is possible to change the properties of matter was a powerful incentive for exploring and controlling its use. To select an appropriate material, we must be familiar with its properties, advantages and limitations. We must also be familiar with its functional characteristics and structure so that we can get an accurate idea of its behaviour when it is used.</p> <p><u>Heat treatments, such as quenching and tempering, make it possible to improve the mechanical properties of steel. For example, quenching increases not only hardness, but also fragility, while tempering improves toughness while reducing elasticity. Annealing makes it possible to restore the original properties of a material. The three characteristic elements of the heat treatment of metals are heating to the critical point, maintaining a uniform temperature and cooling the metal more or less quickly.</u></p> <p>The concepts related to plastics, ceramics and composites tell us about their composition and properties, as well as how they are used and classified.</p> <p>The advent of plastics was a veritable revolution. Their excellent physical properties and numerous qualities, such as resistance and durability and the fact that they lend themselves to high-precision machining, help explain their growing use.</p> <p>The term “ceramic” covers a wide range of materials used in traditional sectors such as construction and the production of consumer goods, as well as in other sectors such as electrotechnology and mechanical construction.</p> <p>Every composite material has specific properties and characteristics. Their strong mechanical properties and low density make them particularly useful. They can be found in a number of modern technological applications.</p> <p>All materials degrade more or less quickly. They can react in one of three ways to their environment: they can undergo a chemical reaction (plastics, ceramics), corrosion or oxidation (metals). Means used to prevent degradation include electrochemical protection, protective coatings and surface treatments.</p>	<ul style="list-style-type: none"> <li>– Constraints (deflection, shearing)</li> <li>– Characteristics of mechanical properties</li> <li>– <u>Heat treatments</u></li> <li>– Types and properties                         <ul style="list-style-type: none"> <li>• Plastics (thermoplastics, thermosetting plastics)</li> <li>• Ceramics</li> <li>• Composites</li> </ul> </li> <li>– Modification of properties (degradation, protection)</li> </ul>
<p><b>Manufacturing</b></p> <p><u>The concepts associated with manufacturing are important prerequisites. They serve as references for the use of different techniques. The study of machines and tools provides an accurate picture of shaping.</u></p> <p><u>Laying out is done before many machining operations, since it makes it possible to configure parts; it is therefore important to be familiar with its major aspects. Drilling and threading are two of the most common manufacturing methods. Materials, rotation speeds and cutting angles (drills) are characteristics of drilling. Choosing a thread profile and pitch (number of threads per inch) makes it possible to determine, among other things, the pitch centre diameter before tapping.</u></p> <p><u>Measurement requires the use of instruments such as vernier calipers and fosters greater precision during machining operations. Consequently, the principles associated with measurement must be learned.</u></p>	<ul style="list-style-type: none"> <li>– <u>Shaping</u> <ul style="list-style-type: none"> <li>• <u>Machines and tools</u></li> </ul> </li> <li>– <u>Manufacturing</u> <ul style="list-style-type: none"> <li>• <u>Characteristics of laying out, drilling, tapping and threading</u></li> </ul> </li> <li>– <u>Measurement</u> <ul style="list-style-type: none"> <li>• <u>Direct measurements (vernier calipers)</u></li> </ul> </li> </ul>

## The Technological World (Cont.)

Orientations	Compulsory Concepts
<p><b>Biotechnology</b></p> <p><u>Cloning generally refers to the reproduction of an individual, a cell tissue, a cell or even a gene. Plants reproduce sexually using seeds, but some of them also reproduce asexually. A distinctive characteristic of this type of reproduction is that the offspring are genetically identical to the parent: this is called plant cloning. This natural phenomenon has been used for centuries, in particular by horticulturists. This type of reproduction relies on in vitro plant cultures, which make it possible to introduce desirable characteristics, such as resistance to a pesticide, the elimination of viruses or the creation of pure lines, into the plants.</u></p> <p><u>Several techniques are used to clone animals. The possible applications are numerous: in basic research, animal cloning helps us understand the functioning of the genome and the embryonic development process. In agronomy, cloning and transgenesis offer many advantages (e.g. higher-yielding, disease-resistant animals). Therapeutic cloning has resulted in advances in the treatment of degenerative diseases, organ transplants and so on. In light of technological advancements and the multiple applications of animal cloning, the question of human cloning, with all its ethical implications, is being raised.</u></p> <p><u>The depollution of wastewater requires a series of steps involving physical, physico-chemical and biological treatments. All of these treatments are characterized by operations such as filtration, decantation, lagooning, and the use of bacterial cultures and active mud. Their goal is to rid wastewater of the coarsest solid waste, to eliminate a large portion of mineral or organic suspended particulates and to remove soluble pollutants such as carbon, nitrogen and phosphorus. In certain cases, other treatments are necessary (e.g. addition of a disinfecting reagent, use of ultraviolet radiation), especially when the water ends up in a particularly sensitive area.</u></p> <p><u>Both economical and environmentally friendly, biological soil depollution treatments are becoming increasingly popular. They use plants or microorganisms to degrade various pollutants. Some bacteria are capable of degrading complex molecules, thereby obtaining the energy they need to live. Phytoremediation is the use of plants to depollute soils, purify wastewater or clean the air in a building. It is used to biologically eliminate metals, pesticides, solvents, oil and other contaminants. The main characteristics of an effective depollutant include the ability to transform a wide range of chemical compounds, to absorb pollutants and to tolerate toxic compounds. However, it is important to remember that no treatment can fully depollute soils contaminated by years of waste accumulation.</u></p>	<ul style="list-style-type: none"><li>- Cloning</li><li>- Wastewater treatment</li><li>- Biodegradation of pollutants</li></ul>

Cultural References			
History	Community resources	Applications	Events
Alexandro Volta Leonardo da Vinci Joseph Brown and Lucian Sharp Le Corbusier Alfred Nobel Rudolph Diesel Henry Ford Frederic Winslow Taylor	Canadian Intellectual Property Office Canadian Patent Database Ordre des ingénieurs du Québec	Production line Interchangeability of parts Computer Home automation Robotics Remote sensing Street lights Clothing, <u>textiles</u> Refrigeration, <u>heating</u> <u>Storage of electrical energy</u> <u>Biofuels</u> <u>Decontamination and rehabilitation of polluted soils and sites</u> <u>Treatment of hazardous waste</u>	Industrial Revolution Establishment of labour standards Globalization <u>International Consortium on the Human Genome Sequencing Project</u>

## SUMMARY TABLE OF THE COMPULSORY CONCEPTS

The Living World	The Material World	The Earth and Space	The Technological World
<p><b>Ecology</b></p> <ul style="list-style-type: none"> <li>– Study of populations (density, biological cycles)</li> <li>– Dynamics of communities <ul style="list-style-type: none"> <li>• Biodiversity</li> <li>• Disturbances</li> </ul> </li> <li>– Dynamics of ecosystems <ul style="list-style-type: none"> <li>• Trophic relationships</li> <li>• Primary productivity</li> <li>• Material and energy flow</li> <li>• Chemical recycling</li> </ul> </li> <li>– <u>Ecological footprint</u></li> <li>– <u>Ecotoxicology</u> <ul style="list-style-type: none"> <li>• <u>Contaminants</u></li> <li>• <u>Bioconcentration</u></li> <li>• <u>Bioaccumulation</u></li> <li>• <u>Toxicity level</u></li> </ul> </li> </ul> <p><b>Genetics</b></p> <ul style="list-style-type: none"> <li>– <u>Heredity</u></li> <li>– <u>Gene</u></li> <li>– <u>Allele</u></li> <li>– <u>Character trait</u></li> <li>– <u>Genotype and phenotype</u></li> <li>– <u>Homozygote and heterozygote</u></li> <li>– <u>Dominance and recessivity</u></li> <li>– <u>Protein synthesis</u></li> <li>– <u>Cross-breeding</u></li> </ul>	<p><b>Physical properties of solutions</b></p> <ul style="list-style-type: none"> <li>– Concentration (ppm, mole/L)</li> <li>– Electrolytes</li> <li>– <u>Strength of electrolytes</u></li> <li>– pH scale</li> <li>– Electrolytic dissociation</li> <li>– Ions</li> <li>– Electrical conductivity</li> </ul> <p><b>Chemical changes</b></p> <ul style="list-style-type: none"> <li>– Combustion</li> <li>– <u>Oxidation</u></li> <li>– Photosynthesis and respiration</li> <li>– Acid-base neutralization reaction</li> <li>– <u>Salts</u></li> <li>– Balancing chemical equations</li> <li>– Law of conservation of mass</li> <li>– <u>Stoichiometry</u></li> <li>– <u>Types of bonds</u> <ul style="list-style-type: none"> <li>• <u>Covalent</u></li> <li>• <u>Ionic</u></li> </ul> </li> <li>– <u>Endothermic and exothermic reactions</u></li> </ul> <p><b>Organization of matter</b></p> <ul style="list-style-type: none"> <li>– Rutherford-Bohr atomic model</li> <li>– Lewis notation</li> <li>– <u>Simplified atomic model</u></li> <li>– <u>Neutron</u></li> <li>– <u>Nomenclature and notation rules</u></li> <li>– <u>Polyatomic ions</u></li> <li>– <u>Concept of mole</u></li> <li>– <u>Avogadro's number</u></li> </ul> <p><b>Periodic table</b></p> <ul style="list-style-type: none"> <li>– Families and periods</li> <li>– <u>Relative atomic mass</u></li> <li>– <u>Atomic number</u></li> <li>– <u>Periodicity of properties</u></li> <li>– <u>Isotopes</u></li> </ul>	<p><b>Biogeochemical cycles</b></p> <ul style="list-style-type: none"> <li>– Carbon cycle</li> <li>– Nitrogen cycle</li> <li>– Phosphorus cycle</li> </ul> <p><b>Climate zones</b></p> <ul style="list-style-type: none"> <li>– Factors that influence the distribution of biomes</li> <li>– Marine biomes</li> <li>– Terrestrial biomes</li> </ul> <p><b>Lithosphere</b></p> <ul style="list-style-type: none"> <li>– Minerals</li> <li>– Permafrost</li> <li>– Energy resources</li> <li>– Soil profile (horizons)</li> <li>– <u>Soil depletion</u></li> <li>– <u>Buffering capacity of the soil</u></li> <li>– <u>Contamination</u></li> </ul> <p><b>Hydrosphere</b></p> <ul style="list-style-type: none"> <li>– Catchment area</li> <li>– Oceanic circulation</li> <li>– Salinity</li> <li>– Glacier and ice floe</li> <li>– Energy resources</li> <li>– <u>Contamination</u></li> <li>– <u>Eutrophication</u></li> </ul> <p><b>Atmosphere</b></p> <ul style="list-style-type: none"> <li>– Greenhouse effect</li> <li>– Atmospheric circulation <ul style="list-style-type: none"> <li>• <u>Prevailing winds</u></li> </ul> </li> <li>– Air mass</li> <li>– Cyclone and anticyclone</li> <li>– Energy resources</li> <li>– <u>Contamination</u></li> </ul> <p><b>Space</b></p> <ul style="list-style-type: none"> <li>– Solar energy flow</li> <li>– Earth-Moon system (gravitational effect)</li> </ul>	<p><b>Graphical language</b></p> <ul style="list-style-type: none"> <li>– <u>Axonometric projection: exploded view (reading)</u></li> <li>– <u>Multiview orthogonal projection (assembly drawing)</u></li> <li>– <u>Dimensional tolerances</u></li> </ul> <p><b>Mechanical engineering</b></p> <ul style="list-style-type: none"> <li>– Characteristics of linking of mechanical parts</li> <li>– <u>Adhesion and friction between parts</u></li> <li>– <u>Degrees of freedom of a part</u></li> <li>– Guiding controls</li> <li>– Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)</li> <li>– Speed changes</li> <li>– Construction and characteristics of motion transformation systems (screw gear system, cams, <u>eccentrics</u>, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)</li> </ul> <p><b>Electrical engineering</b></p> <ul style="list-style-type: none"> <li>– Power supply</li> <li>– Conduction, insulation and protection (<u>resistance and coding, printed circuit</u>)</li> <li>– Typical command functions (<u>lever, pushbutton, toggle, unipolar, bipolar, unidirectional, bidirectional</u>)</li> <li>– Transformation of energy (electricity and light, heat, vibration, magnetism)</li> <li>– <u>Other functions (condenser, diode)</u></li> </ul>

## SUMMARY TABLE OF THE COMPULSORY CONCEPTS (CONT.)

The Living World	The Material World	The Earth and Space	The Technological World
	<p><b><u>Nuclear transformations</u></b></p> <ul style="list-style-type: none"> <li>– Nuclear stability</li> <li>– Radioactivity</li> <li>– Fission and fusion</li> </ul> <p><b><u>Electricity and electromagnetism</u></b></p> <p><b><u>Electricity</u></b></p> <ul style="list-style-type: none"> <li>– Electrical charge</li> <li>– Static electricity</li> <li>– Ohm's law</li> <li>– Electrical circuits</li> <li>– Kirchhoff's laws</li> <li>– Relationship between power and electrical energy</li> <li>– Electrical field</li> <li>– Coulomb's law</li> </ul> <p><b><u>Electromagnetism</u></b></p> <ul style="list-style-type: none"> <li>– Forces of attraction and repulsion</li> <li>– Magnetic field of a live wire</li> <li>– Magnetic field of a solenoid</li> </ul> <p><b><u>Transformation of energy</u></b></p> <ul style="list-style-type: none"> <li>– Law of conservation of energy</li> <li>– Energy efficiency</li> <li>– Distinction between heat and temperature</li> <li>– Relationship between work, force and travel</li> <li>– Relationship between mass and weight</li> <li>– Effective force</li> <li>– Relationship between work and energy</li> <li>– Relationship between potential energy, mass, acceleration and travel</li> <li>– Relationship between kinetic energy, mass and velocity</li> <li>– Relationship between heat energy, specific heat capacity, mass and temperature variations</li> </ul>		<p><b><u>Materials</u></b></p> <ul style="list-style-type: none"> <li>– Constraints (deflection, shearing)</li> <li>– Characteristics of mechanical properties</li> <li>– Heat treatments</li> <li>– Types and properties <ul style="list-style-type: none"> <li>• Plastics (thermoplastics, thermosetting plastics)</li> <li>• Ceramics</li> <li>• Composites</li> </ul> </li> <li>– Modification of properties (degradation, protection)</li> </ul> <p><b><u>Manufacturing</u></b></p> <ul style="list-style-type: none"> <li>– Shaping <ul style="list-style-type: none"> <li>• Machines and tools</li> </ul> </li> <li>– Manufacturing <ul style="list-style-type: none"> <li>• Characteristics of laying out, drilling, tapping and threading</li> </ul> </li> <li>– Measurement <ul style="list-style-type: none"> <li>• Direct measurements (vernier calipers)</li> </ul> </li> </ul> <p><b><u>Biotechnology</u></b></p> <ul style="list-style-type: none"> <li>– Cloning</li> <li>– Wastewater treatment</li> <li>– Biodegradation of pollutants</li> </ul>

## Methods, Strategies, Attitudes and Techniques

This section addresses the methods, strategies, attitudes and techniques recommended in the programs. While they are different from the concepts, these elements are just as important in the development of competencies. They build on the elements encountered in the first year of Cycle Two.

### Methods

Although they are different from the concepts, the methods are just as important in the development of competencies and so require special attention. They should not be applied in isolation, but in learning and evaluation situations in which several of them are combined. The ability to apply these methods in combination is an indicator of proficiency.

Seven methods are presented: modelling, the observation, experimental and empirical methods, formation of an opinion, the technological design process and technological analysis.

### Modelling

Modelling consists in constructing a representation of an abstract situation, one that is difficult to observe or impossible to see. This representation can be a text, a drawing, a mathematical formula, a chemical equation, a software program or a scale model. Over time, the model becomes more refined and complex. It may be valid only for a certain amount of time and in a specific context and, in many cases, it must be modified or rejected. It is also important to consider the context in which it was created. A model must have certain characteristics. Among other things, it must help people understand a given reality, explain certain properties of that reality and predict new observable phenomena.

### Observation method

The observation method is an active process intended to help the observer interpret facts on the basis of his or her predetermined criteria and generally accepted criteria within a given field. In light of the information collected, the students gain a new understanding of the facts, which is inextricably linked to the context in which the observations were made. In his or her interpretation and organization of information, the observer reinterprets the physical world on the basis of his or her assumptions and the conceptual schemes that are an integral part of what he or she brings to the observation process. All observations involve a theoretical model established by the observer.

### Experimental method

The experimental method begins with the formulation of preliminary explanations. Then students can begin looking for an answer and defining the framework of the experiment. They must develop an experimental procedure in order to identify a certain number of variables to be manipulated. The aim of the procedure is to identify and compare observable or quantifiable elements and check them against the initial hypotheses. Moving back and forth between the different stages of the experimental method raises new questions and allows students to formulate new hypotheses, adjust the experimental procedure and take the limitations of the experiment into account.

### *Empirical method*

The empirical method involves finding a situation in which there is no manipulation of variables. Its spontaneity does not detract from the methodology involved (for example, a survey is an empirical approach that leaves nothing to chance). Often based on intuitive models, this method sometimes provides a way of exploring and representing the elements of a problem. Often, it can lead to a number of preliminary ideas, hypotheses and theories, as well as new techniques and possible avenues for other research projects.

### *Formation of an opinion*

When called upon to form an opinion and develop arguments related to a scientific or technological issue, students must be aware of how their knowledge, beliefs and values can influence their judgment. They must therefore realize how the acquisition and application of knowledge (subject-related, epistemological and contextual) and more general skills can contribute to the formation of an informed opinion. Like other methods, this one involves interpreting and comparing information, recognizing biases and assumptions, reasoning by analogy, and taking into account seemingly contradictory facts. It allows students to develop solid arguments and justify their conclusions. By the end of the process, the students learn that it is necessary to consult several sources, that contradictions between sources are common and need to be interpreted, and that the choice of a solution can depend on a number of factors.

### *Technological design process*

This process is used when a need has been identified. The resulting study of the technological problem must take into account any conditions and constraints in the specifications. Then the real design process begins: finding solutions to operational and construction problems, defining shapes, determining the necessary materials, and designing parts.

Creating, testing and validating a prototype complete the process. By carefully examining the prototype they have designed and the results of the tests, students can evaluate their solution and check it against the requirements in the specifications. The design process, which requires logic, precision, abstraction and execution, enables students to move from the reasoning stage to the practical stage. Reflective reviews during and at the end of the process enable students to analyze their progress, validate their choices and, if necessary, suggest improvements to the chosen solution.

### *Technological analysis*

To analyze a technical object or technological system, students must determine its overall function so that they can identify the need it satisfies. They must identify the different components in order to determine their respective functions. If necessary, the technical object or technological system can be disassembled in order to provide a better understanding of its construction and operation. This process reveals the object or system as a concrete and tangible combination of solutions adapted to meet a need.

## STRATEGIES

Some strategies used in science and technology can help students develop the program's three competencies.

EXPLORATION STRATEGIES	ANALYTICAL STRATEGIES
<ul style="list-style-type: none"><li>– Collecting as much scientific, technological and contextual information as possible to define a problem or predict patterns</li><li>– Referring to similar problems that have already been solved</li><li>– Generalizing on the basis of several structurally similar cases</li><li>– Anticipating the results of a method</li><li>– Developing various scenarios</li><li>– Exploring various possible solutions</li><li>– Considering various points of view on scientific or technological issues</li></ul>	<ul style="list-style-type: none"><li>– Identifying the constraints and important elements related to the problem-solving situation</li><li>– Dividing a complex problem into simpler subproblems</li><li>– Using different types of reasoning (e.g. inductive and deductive reasoning, comparison, classification, prioritization) in order to process information</li><li>– Reasoning by analogy in order to process information and adapt scientific and technological knowledge</li><li>– Selecting relevant criteria to help him/her determine where he/she stands on a scientific or technological issue</li></ul>

## ATTITUDES

The adoption of a variety of attitudes makes it easier for students to invest in the methods used and to develop a sense of responsibility for their own actions and with respect to society in general. Attitudes are an important factor in the development of the competencies.

INTELLECTUAL ATTITUDES	BEHAVIOURAL ATTITUDES
<ul style="list-style-type: none"> <li>– Curiosity</li> <li>– Sense of initiative</li> <li>– An inclination to take intellectual risks</li> <li>– Interest in comparing different ideas</li> <li>– Receptivity to original solutions</li> <li>– Intellectual rigour</li> <li>– Objectivity</li> <li>– Methodical approach to their work</li> <li>– <u>Concern for the precision of measurements</u></li> <li>– Concern about using proper and precise language</li> </ul>	<ul style="list-style-type: none"> <li>– Discipline</li> <li>– Independence</li> <li>– <u>Concern for effectiveness</u></li> <li>– <u>Concern for efficiency</u></li> <li>– Perseverance</li> <li>– Concern for a job well done</li> <li>– Sense of responsibility</li> <li>– Willingness to work hard</li> <li>– Willingness to cooperate effectively with others</li> <li>– Concern for health and safety</li> <li>– Respect for life and the environment</li> <li>– Attentiveness</li> <li>– Respect for themselves and others</li> <li>– Team spirit</li> <li>– International solidarity in dealing with major issues</li> </ul>

## TECHNIQUES

Often essential, techniques involve methodical procedures that provide guidelines for the proper application of theoretical knowledge. These procedures are divided into two major categories: scientific techniques and technological techniques.

TECHNOLOGICAL TECHNIQUES		SCIENTIFIC TECHNIQUES
Graphical language	Manufacturing	Manipulations
<p><b>Techniques:</b></p> <ul style="list-style-type: none"> <li>– Using scales</li> <li>– Constructing a graph using instruments (multiview orthogonal projection, isometric representation, perspective drawing)</li> <li>– Drawing schematic diagrams</li> </ul>	<p><b>Techniques:</b></p> <ul style="list-style-type: none"> <li>– Safely using machines and tools (e.g. band saw, drill, sander, hammer, screwdriver, pliers)</li> <li>– Measuring and laying out</li> <li>– Machining (e.g. sawing, drilling, filing, stripping, splicing, soldering, welding)</li> <li>– Finishing</li> <li>– Performing verification and control tasks</li> <li>– Assembling and disassembling</li> <li>– Making a part</li> </ul>	<p><b>Techniques:</b></p> <ul style="list-style-type: none"> <li>– Safely using laboratory materials and equipment</li> <li>– Using observational instruments</li> <li>– Preparing solutions</li> <li>– Collecting samples</li> </ul>
TECHNOLOGICAL AND SCIENTIFIC TECHNIQUES		
<p><b>Measuring techniques:</b></p> <ul style="list-style-type: none"> <li>– <u>Verifying the repeatability, accuracy and precision of measuring instruments</u></li> <li>– <u>Using measuring instruments</u></li> </ul>		
<ul style="list-style-type: none"> <li>– <u>Interpreting results (significant digits, measurement errors)</u></li> </ul>		

This section describes the environmental issues proposed in the programs. They are social issues whose scientific and technological aspects are conducive to the development of the three subject-specific competencies and to the acquisition of concepts. Since these issues are not compulsory, teachers may select others in order to mobilize the same concepts. The description of each issue is followed by a schematic diagram of the related conceptual networks.

### Climate Change

Climate change is one of the major challenges humanity will have to face. The most urgent problem is the rise in the average temperature of the Earth. There are a number of theories as to the causes of this phenomenon, but the greenhouse effect is the most commonly accepted by the scientific community.

The greenhouse effect is first and foremost a natural phenomenon. Sunlight passes through the Earth's atmosphere and heats the surface of the planet, which, in turn, reflects heat into space. This infrared radiation is absorbed in part by certain gases and water vapour in the atmosphere, keeping it close to the Earth. If there were no greenhouse gases (carbon dioxide, methane and nitrous oxide), most of the heat that penetrates the Earth's atmosphere would quickly return to space, and the average temperature of the Earth would be  $-18^{\circ}\text{C}$  instead of  $15^{\circ}\text{C}$ .

The concentration of greenhouse gases has varied over the course of the Earth's history. However, it appears that the amount of carbon dioxide and methane in the atmosphere has not been this high in 420 000 years, and that the amount of nitrous oxide is higher than it has been in at least a thousand years. The concentration of these gases has increased rapidly since the beginning of industrialization, a period characterized by an increase in the population and in the demand for energy, and by changes in land use patterns. By burning enormous quantities of fossil fuels (coal, oil and natural gas), which generate a significant amount of  $\text{CO}_2$ , and by clear-cutting forests, which hampers the natural process of  $\text{CO}_2$  transformation, we

magnified the natural greenhouse effect and are now experiencing an increase in the Earth's average temperature.

Global warming, which is probably related to an increase in the greenhouse effect, affects every aspect of climate because it brings about changes in atmospheric and oceanic circulation. This has a number of consequences, some of which have already been observed. They include changes in the rain cycle, more frequent extreme weather phenomena and permafrost thawing. We also anticipate the accelerated melting of glaciers and ice floes, which will cause a rise in sea level. This will result in floods and coastline erosion, which will force certain populations to move and require changes in the way land is used. These environmental changes will inevitably have a significant impact on socioeconomic activity throughout the world. Forestry, fishing, water management, tourism, and energy production and consumption will be particularly affected.

In Québec, climate change could affect the quality of our water, endangering human health and the balance of ecosystems. It could also cause fluctuations in the level of the Great Lakes and the flow of the St. Lawrence River. These fluctuations would have various consequences for the marine transportation industry, which relies on the St. Lawrence Seaway. They would also disrupt certain ecosystems, through habitat loss or deteriorating living conditions for some species of fish. Variations in precipitation would undoubtedly affect agricultural productivity and biodiversity in Québec. Moreover, coastal erosion and more frequent freezes and thaws would have an impact on the road network. Finally, if the permafrost thaws, soils in the far north could become unstable, affecting the population there.

## The Living World

### Ecology

- Study of populations (density, biological cycles)
- Dynamics of communities
  - Biodiversity
  - Disturbances
- Dynamics of ecosystems
  - Trophic relationships
  - Primary productivity
  - Material and energy flow
  - Chemical recycling
- Ecotoxicology
  - Contaminants

## The Technological World

### Graphical language

- Axonometric projection: exploded view (reading)
- Multiview orthogonal projection (assembly drawing)
- Dimensional tolerances

### Mechanical engineering

- Characteristics of linking of mechanical parts
- Adhesion and friction between parts
- Degrees of freedom of a part
- Guiding controls
- Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)
- Speed changes

- Construction and characteristics of motion transformation systems (screw gear system, cams, eccentrics, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)

### Electrical engineering

- Power supply
- Conduction, insulation and protection (resistance and coding, printed circuit)
- Typical command functions (lever, pushbutton, toggle, unipolar, bipolar, unidirectional, bidirectional)
- Transformation of energy (electricity and light, heat, vibration, magnetism)
- Other functions (condenser, diode)

### Materials

- Constraints (deflection, shearing)
- Characteristics of mechanical properties
- Heat treatments
- Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - Composites
- Modification of properties (degradation, protection)

### Manufacturing

- Shaping
  - Machines and tools
  - Manufacturing
- Characteristics of laying out, drilling, tapping and threading
- Measurement
  - Direct measurements (vernier calipers)

## CLIMATE CHANGE

## The Earth and Space

### Biogeochemical cycles

- Carbon cycle
- Nitrogen cycle

### Climate zones

- Factors that influence the distribution of biomes
- Marine biomes
- Terrestrial biomes

### Lithosphere

- Permafrost

### Hydrosphere

- Catchment area
- Oceanic circulation
- Salinity
- Glacier and ice floe

### Atmosphere

- Greenhouse effect
- Atmospheric circulation
- Air mass
- Cyclone and anticyclone
- Contamination

### Space

- Solar energy flow

## The Material World

### Chemical changes

- Combustion
- Photosynthesis and respiration
- Balancing chemical equations
- Stoichiometry
- Endothermic and exothermic reactions

### Organization of matter

- Rutherford-Bohr atomic model
- Simplified atomic model
- Lewis notation
- Nomenclature and notation rules
- Polyatomic ions
- Concept of mole
- Avogadro's number

### Periodic table

- Families and periods
- Relative atomic mass
- Atomic number
- Periodicity of properties

### Transformation of energy

- Distinction between heat and temperature
- Relationship between heat energy, specific heat capacity, mass and temperature variations
- Relationship between work, force and travel
- Relationship between work and energy
- Relationship between potential energy, mass, acceleration and travel
- Relationship between kinetic energy, mass and velocity

## Drinking water

Water is a basic substance and a very precious natural resource with extensive applications in home life, agriculture, industry and recreation. Because of its vital importance, the United Nations has decreed access to drinking water a basic human right.

Although our planet is called the *blue planet* because much of it is covered by water, very little of that water is easily accessible to humans. Salt water is unfit for human consumption and can be toxic in excessive quantities. That leaves natural fresh water, far less bountiful, unequally distributed over the Earth's surface and often difficult to access because it is trapped in continental glaciers or in the water table.

Not only is fresh water a rare resource, but it is also subject to pollution and waste. A slight imbalance in its characteristics can make it unfit for human consumption. A decomposing animal carcass, a slight variation in pH level or contamination by a few parts per million of a heavy metal can render water toxic. Today, despite the laws and regulations in effect, many sources of fresh water are polluted by different toxic chemical releases, which often result in the proliferation of harmful microorganisms.

Combined with contamination, the waste of fresh water is another important issue. The average North American consumes an average of several hundred thousand litres of water a year, more than half of which is wasted. In reality, a human being needs only about ten thousand litres of water a year to live.

Québec has a large water system, which is considered a world drinking water reserve. A government water policy is aimed at protecting and raising awareness of our water heritage.

## The Living World

### Ecology

- Study of populations (density, biological cycles)
- Dynamics of communities
  - Biodiversity
  - Disturbances
- Dynamics of ecosystems
  - Trophic relationships
  - Primary productivity
  - Material and energy flow
  - Chemical recycling
- Ecotoxicology
  - Contaminants
  - Bioconcentration
  - Bioaccumulation
  - Toxicity threshold

## The Technological World

### Graphical language

- Axonometric projection: exploded view (reading)
- Multiview orthogonal projection (assembly drawing)
- Dimensional tolerances

### Mechanical engineering

- Characteristics of linking of mechanical parts
- Adhesion and friction between parts
- Degrees of freedom of a part
- Guiding controls
- Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)
- Speed changes
- Construction and characteristics of motion transformation systems (screw gear system, cams, eccentrics, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)

### Electrical engineering

- Power supply
- Conduction, insulation and protection (resistance and coding, printed circuit)
- Typical command functions (lever, push-button, toggle, unipolar, bipolar, unidirectional, bidirectional)
- Transformation of energy (electricity and light, heat, vibration, magnetism)
- Other functions (condenser, diode)

### Materials

- Constraints (deflection, shearing)
- Characteristics of mechanical properties
- Heat treatments
- Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - Composites
- Modification of properties (degradation, protection)

### Manufacturing

- Shaping
  - Machines and tools
- Manufacturing
  - Characteristics of laying out, drilling, tapping and threading
- Measurement
  - Direct measurements (vernier calipers)

### Biotechnology

- Wastewater treatment
- Biodegradation of pollutants

## DRINKING WATER

## The Earth and Space

### Climate zones

- Marine biomes
- Terrestrial biomes

### Hydrosphere

- Catchment area
- Oceanic circulation
- Salinity
- Glacier and ice floe
- Contamination
- Eutrophication

### Atmosphere

- Atmospheric circulation
  - Prevailing winds
- Contamination

## The Material World

### Physical properties of solutions

- Concentration (ppm, mole/L)
- Electrolytes
- Strength of electrolytes
- pH scale
- Electrolytic dissociation
- Ions
- Electrical conductivity

### Chemical changes

- Acid-base neutralization reaction
- Balancing chemical equations
- Stoichiometry
- Types of bonds
  - Covalent
  - Ionic

### Organization of matter

- Rutherford-Bohr atomic model
- Simplified atomic model
- Lewis notation
- Families and periods
- Nomenclature and notation rules
- Polyatomic ions
- Concept of mole
- Avogadro's number

## Deforestation

Forests are among the Earth's natural treasures. They have been part of the landscape of the world for thousands of years and they contribute to the environmental and climatic processes on which biodiversity and human life depend.

In recent centuries, large areas of forest have been destroyed on many continents to meet the need for food and because of the growth of the residential and industrial areas of cities. The reduction of forested areas and the permanent use of this land for other purposes is called deforestation.

However, large forested areas still exist in spite of temporary changes resulting from harvesting of the forests or natural disturbances.

Over the years, the world's forest cover has undergone various natural disturbances through fire, leaf-eating insects or freezing rain. Such events are an integral part of the mechanisms of regeneration of forests and, along with forest harvesting, they help to renew forests and ensure their viability.

Deforestation in some countries in South America, Asia and Africa has major consequences for the environment and for society. It has negative effects on biodiversity, because the majority of the world's plants and animals live in forests. It also has a major impact on climate change, because growing trees fix carbon and release oxygen. Trees processed to manufacture things store this carbon (carbon sink), while trees that die and decompose or burn release it (carbon-neutral).

Forests also regulate the flow of rivers and streams by absorbing excess rainwater and then gradually releasing it. They reduce the force of the winds that dry out and erode the soil, causing loss of fertility, and aggravating the damage caused by natural disasters. Thus, in some environments, deforestation is the first step toward desertification.

Deforestation directly affects hundreds of millions of people in the world who live in or near forests. These populations depend on the forest to meet their basic needs by providing them with food and wood for building and heating.

Forests are an important resource in Québec. Various measures have been implemented to protect them. Sustainable forest management and the creation of protected areas make it possible to protect other resources of the forest, such as wildlife, water and scenery.

## The Living World

### Ecology

- Study of populations (density, biological cycles)
- Dynamics of communities
  - Biodiversity
  - Disturbances
- Dynamics of ecosystems
  - Trophic relationships
  - Primary productivity
  - Material and energy flow
  - Chemical recycling
- Ecological footprint

### Genetics

- Heredity
- Gene
- Allele
- Character trait
- Genotype and phenotype
- Homozygote and heterozygote
- Dominance and recessivity
- Protein synthesis
- Cross-breeding

## The Technological World

### Graphical language

- Axonometric projection: exploded view (reading)
- Multiview orthogonal projection (assembly drawing)
- Dimensional tolerances

### Mechanical engineering

- Characteristics of linking of mechanical parts
- Adhesion and friction between parts
- Degrees of freedom of a part
- Guiding controls
- Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)
- Speed changes

- Construction and characteristics of motion transformation systems (screw gear system, cams, eccentrics, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)

### Electrical engineering

- Power supply
- Conduction, insulation and protection (resistance and coding, printed circuit)
- Typical command functions (lever, pushbutton, toggle, unipolar, bipolar, unidirectional, bidirectional)
- Transformation of energy (electricity and light, heat, vibration, magnetism)
- Other functions (condenser, diode)

### Materials

- Constraints (deflection, shearing)
- Characteristics of mechanical properties
- Heat treatments

- Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - Composites
- Modification of properties (degradation, protection)

### Manufacturing

- Shaping
  - Machines and tools
- Manufacturing
  - Characteristics of laying out, drilling, tapping and threading
- Measurement
  - Direct measurements (vernier calipers)

### Biotechnology

- Cloning
- Biodegradation of pollutants

## DEFORESTATION

## The Earth and Space

### Biogeochemical cycles

- Carbon cycle
- Nitrogen cycle
- Phosphorus cycle

### Climate zones

- Factors that influence the distribution of biomes
- Marine biomes
- Terrestrial biomes

### Lithosphere

- Minerals
- Energy resources
- Soil depletion
- Buffering capacity of the soil
- Contamination

### Hydrosphere

- Catchment area
- Oceanic circulation
- Contamination
- Eutrophication

### Atmosphere

- Greenhouse effect
- Atmospheric circulation

### Space

- Solar energy flow

## The Material World

### Chemical changes

- Combustion
- Oxidation
- Photosynthesis and respiration
- Balancing chemical equations

### Organization of matter

- Rutherford-Bohr atomic model
- Lewis notation

### Periodic table

- Families and periods

### Transformation of energy

- Distinction between heat and temperature
- Law of conservation of energy

## Energy

Controlling energy resources was an important factor in the development of humankind. It enabled us to extend our control over the earth as a whole and to explore space. History shows how we have met various energy-related challenges.

In addition to the topic “The Energy Challenge” presented in the second year of the Science and Technology program, this program raises the issue of energy per se. It is addressed primarily from the point of view of transformations. Energy is present in the environment in different forms. Making use of this energy implies transformations that have an impact on ecosystems.

While the transformation of certain energy resources produces waste that is difficult to manage, other sources of less polluting energy generate less efficient energy. The study of the production, distribution and use of energy can guide our personal and collective energy choices.

In Québec, this problem is fueled by local and regional issues related to the development of hydroelectricity, the creation of wind farms, the debate over the use of nuclear energy and the development of alternative forms of energy such as biomass, solar energy, geothermal energy and tidal energy.

## The Living World

### Ecology

- Dynamics of ecosystems
  - Trophic relationships
  - Primary productivity
  - Material and energy flow
  - Chemical recycling

## The Technological World

### Mechanical engineering

- Characteristics of linking of mechanical parts
- Adhesion and friction between parts
- Degrees of freedom of a part
- Guiding controls
- Construction and characteristics of motion transmission systems (friction gears, pulleys and belts, gear assembly, sprocket wheels and chain, wheel and worm gear)
- Speed changes
- Construction and characteristics of motion transformation systems (screw gear system, cams, eccentrics, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)

### Electrical engineering

- Power supply
- Conduction, insulation and protection (resistance and coding, printed circuit)
- Typical command functions (lever, pushbutton, toggle, unipolar, bipolar, unidirectional, bidirectional)
- Transformation of energy (electricity and light, heat, vibration, magnetism)
- Other functions (condenser, diode)

### Materials

- Constraints (deflection, shearing)
- Characteristics of mechanical properties
- Heat treatments
- Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - Composites
- Modification of properties (degradation, protection)

### Graphical language

- Axonometric projection: exploded view (reading)
- Multiview orthogonal projection (assembly drawing)
- Dimensional tolerances

### Manufacturing

- Shaping
  - Machines and tools
- Manufacturing
  - Characteristics of laying out, drilling, tapping and threading
- Measurements
  - Direct measurements (vernier calipers)

# ENERGY

## The Earth and Space

### Biogeochemical cycles

- Carbon cycle
- Nitrogen cycle

### Climate zones

- Factors that influence the distribution of biomes
- Marine biomes
- Terrestrial biomes

### Lithosphere

- Minerals
- Energy resources

### Hydrosphere

- Catchment area
- Oceanic circulation
- Energy resources

### Atmosphere

- Greenhouse effect
- Atmospheric circulation
  - Prevailing winds
- Air mass
- Cyclone and anticyclone
- Energy resources

### Space

- Solar energy flow
- Earth-Moon system (gravitational effect)

## The Material World

### Organization of matter

- Lewis notation
- Neutron
- Simplified atomic model
- Nomenclature and notation rules
- Concept of mole
- Polyatomic ions
- Avogadro's number

### Periodic table

- Families and periods
- Relative atomic mass
- Atomic number
- Periodicity of properties
- Isotopes

### Chemical changes

- Combustion
- Endothermic and exothermic reactions

### Transformation of mechanical energy

- Law of conservation of energy
- Energy efficiency
- Distinction between heat and temperature
- Relationship between work, force and travel
- Effective force
- Relationship between work and energy
- Relationship between potential energy, mass, acceleration and travel
- Relationship between mass and weight
- Relationship between kinetic energy, mass and velocity
- Relationship between heat energy, mass, specific heat capacity and temperature

### Nuclear transformations

- Nuclear stability
- Radioactivity
- Fission and fusion

### Electricity and electromagnetism

#### Electricity

- Electrical charge
- Static electricity
- Ohm's law
- Kirchhoff's laws
- Electrical circuits
- Relationship between power and electrical energy
- Electrical field
- Coulomb's law

#### Electromagnetism

- Forces of attraction and repulsion
- Magnetic field of a live wire
- Magnetic field of a solenoid

## Residual Materials

In different societies throughout the world, many things have a price to be evaluated or negotiated. The wealthiest societies consume vast quantities of goods and services. And the more they consume, the more waste they produce. Per capita waste production is directly proportional to a country's level of economic development.

Too often, vast quantities of waste are inadequately managed, dumped in landfill sites without environmental safety measures. These practices compromise public health and the balance of ecosystems. Waste in the environment is the source of various problems such as smog, the greenhouse effect, acid rain, soil contamination, the bioaccumulation of contaminants and contamination of the water supply.

Residual materials are something we do not necessarily need to eliminate, but to manage effectively. Seeing them in this way helps us understand the need to change current residual materials management practices and habits. There are many alternatives to throwing things away and causing pollution, such as reducing, repairing, recycling, reusing, recovering, reclaiming and educating. These solutions all aim at changing behaviours and using the appropriate technologies.

A number of policies have been adopted in Québec to manage residual materials. Of them, the Residual Materials Management Policy aims at reclaiming 65 per cent of our collective waste. To this end, every municipality in Québec has had to adopt a residual materials management plan in order to achieve this goal.

## The Living World

### Ecology

- Ecotoxicology
  - Contaminants
  - Bioconcentration
  - Bioaccumulation
  - Toxicity threshold
- Study of populations (density, biological cycles)
- Dynamics of communities
  - Biodiversity
  - Disturbances
- Dynamics of ecosystems
  - Trophic relationships
  - Primary productivity
  - Material and energy flow
  - Chemical recycling

## The Technological World

### Mechanical engineering

- Characteristics of linking of mechanical parts
- Adhesion and friction between parts
- Degrees of freedom of a part
- Guiding controls
- Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)
- Speed changes
- Construction and characteristics of motion transformation systems (screw gear system, cams, eccentrics, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)

### Electrical engineering

- Power supply
- Conduction, insulation and protection (resistance and coding, printed circuit)
- Typical command functions (lever, push-button, toggle, unipolar, bipolar, unidirectional, bidirectional)

- Transformation of energy (electricity and light, heat, vibration, magnetism)
- Other functions (condenser, diode)

### Materials

- Constraints (deflection, shearing)
- Characteristics of mechanical properties
- Heat treatments
- Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - Composites
- Modification of properties (degradation, protection)

### Graphical language

- Axonometric projection: exploded view (reading)
- Multiview orthogonal projection (assembly drawing)
- Dimensional tolerances

### Manufacturing

- Shaping
  - Machines and tools
- Manufacturing
  - Characteristics of laying out, drilling, tapping and threading
- Measurement
  - Direct measurements (vernier calipers)

### Biotechnology

- Wastewater treatment
- Biodegradation of pollutants

## RESIDUAL MATERIALS

## The Earth and Space

### Lithosphere

- Buffering capacity of the soil
- Soil degradation
- Contamination

### Hydrosphere

- Contamination
- Eutrophication

### Atmosphere

- Greenhouse effect
- Atmospheric circulation
  - Prevailing winds
- Contamination

### Biogeochemical cycles

- Carbon cycle
- Nitrogen cycle
- Phosphorus cycle

## The Material World

### Physical properties of solutions

- Concentration (ppm, mole/L)
- Electrolytes
- Electrolytic dissociation
- Strength of electrolytes
- pH scale

### Chemical changes

- Combustion
- Oxidation
- Acid-base neutralization reaction
- Photosynthesis and respiration
- Balancing chemical equations
- Law of conservation of mass
- Salts
- Stoichiometry
- Types of bonds
  - Covalent
  - Ionic
- Endothermic and exothermic reactions

### Nuclear transformations

- Nuclear stability
- Radioactivity
- Fission and fusion

### Organization of matter

- Neutron
- Simplified atomic model
- Lewis notation
- Nomenclature and notation rules
- Concept of mole
- Polyatomic ions
- Avogadro's number

### Periodic table

- Families and periods
- Relative atomic mass
- Atomic number
- Periodicity of properties
- Isotopes

## Food Production

With more than six billion inhabitants, our planet is paying the price for our food choices. Everything we eat comes from the earth, and it was farmed, harvested, processed, packaged, distributed and transported by millions of individuals. If we had to feed the entire planet based on North American eating habits, most of the world's energy would go into food production.

The image of the traditional farmer living in tune with nature's rhythms and selling produce at market no longer conforms to Western reality. Today, the agricultural world is controlled by industrial producers. To achieve returns to scale, companies use specialized machines that consume vast quantities of energy. Despite emerging alternatives (e.g. organic farming), the concentration of food production in the hands of large international companies tends to standardize food products and to condition consumer habits based on the imperatives of profitability. Industrial agricultural practices often result in a decrease in the diversity of crops. Given the complexity of the distribution networks, mass production requires the use of preservatives to avoid deterioration of foods during transportation.

The quantity of energy consumed in the industrial production and distribution of food products and the resulting waste threaten the health of the environment. The energy value of foods is often less than the amount of energy resources required to produce and distribute them. For example, for most crops, it is necessary to spend far more kilojoules in oil energy than the energy yield in nutritional value.

Western eating habits are diverse and conform to aesthetic criteria that have a definite impact on the health of the environment. To obtain perfect-looking foods, it is necessary to preserve them from external forces while they are being transported and stored. Transporting foods to our table requires an entire series of technological processes that consume large amounts of energy and produce pollutants. Moreover, the proliferation of sometimes useless packaging and the use of refined, coloured or enriched products, produce waste that can be extremely harmful for the biosphere.

There are also issues related to recent advances in genetic engineering. Genetically modified crop seeds offer new ways of increasing profitability. These biotechnologies enable us to manipulate target characteristics and to broaden the range of possible gene combinations among different species. For example, we can produce soy beans that are impervious to herbicides, insect-resistant corn and tomatoes that can resist viruses. The advantages of producing genetically modified organisms include the possibility of solving food production problems in ecosystems poor in food resources, and the possibility of cornering the market by controlling rights and patents for new crop seeds—a controversial practice in itself.

Everyday individual consumer choices could have a significant impact on the energy and environmental balance sheet for the foods we eat. Inspired by the principle of reducing, repairing, recycling, reusing, recovering and reclaiming, the principle of purchasing unpackaged, unprocessed, local and fair trade foods<sup>15</sup> is a tentative solution based on changing the consumer behaviours of individuals.

Food production is a concern in Québec today. It involves land management: the amount of arable land is decreasing and various changes, with sometimes worrisome consequences, are taking place in agricultural techniques. Nevertheless, recent trends such as the explosion of the organic and fair food trades and measures taken to ensure healthy eating in schools are some of the concrete solutions being applied to the problem.

15. Laure Waridel, *L'envers de l'assiette et quelques idées pour la remettre à l'endroit* (Montréal: Écosociété and Environnement Jeunesse, 2003).

## The Material World

### Chemical changes

- Photosynthesis and respiration

### Transformation of mechanical energy

- Law of conservation of energy
- Energy efficiency
- Relationship between work and energy

## The Technological World

### Mechanical engineering

- Characteristics of linking of mechanical parts
- Adhesion and friction between parts
- Degrees of freedom of a part
- Guiding controls
- Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)
- Speed changes
- Construction and characteristics of motion transformation systems (screw gear systems, cams, eccentrics, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)

### Electrical engineering

- Power supply
- Conduction, insulation and protection (resistance and coding, printed circuit)
- Typical command functions (lever, push-button, toggle, unipolar, bipolar, unidirectional, bidirectional)

- Transformation of energy (electricity and light, heat, vibration, magnetism)
- Other functions (condenser, diode)

### Materials

- Constraints (deflection, shearing)
- Characteristics of mechanical properties
- Heat treatments
- Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - Composites
- Modification of properties (degradation, protection)

### Graphical language

- Axonometric projection: exploded view (reading)
- Multiview orthogonal projection (assembly drawing)
- Dimensional tolerances

### Manufacturing

- Shaping
  - Machines and tools
- Manufacturing
  - Characteristics of laying out, drilling, tapping and threading
- Measurement
  - Direct measurements (vernier calipers)

### Biotechnology

- Cloning

## FOOD PRODUCTION

## The Earth and Space

### Biogeochemical cycles

- Carbon cycle
- Nitrogen cycle
- Phosphorus cycle

### Lithosphere

- Minerals
- Soil depletion
- Contamination

### Hydrosphere

- Contamination
- Eutrophication

### Atmosphere

- Contamination

## The Living World

### Ecology

- Study of populations (density, biological cycles)
- Dynamics of communities
  - Biodiversity
  - Disturbances
- Dynamics of ecosystems
  - Trophic relationships
  - Primary productivity
  - Material and energy flow
  - Chemical recycling
- Ecological footprint
- Ecotoxicology
  - Contaminants
  - Bioconcentration
  - Bioaccumulation
  - Toxicity threshold

### Genetics

- Heredity
- Gene
- Cross-breeding
- Allele
- Character trait
- Genotype and phenotype
- Homozygote and heterozygote
- Dominance and recessivity
- Protein synthesis

## APPENDIX B – EXAMPLES OF APPLICATIONS RELATED TO ENVIRONMENTAL ISSUES

Like the environmental issues, the examples of objects, systems, products and processes listed below are not compulsory elements of the program. They may, however, be used to contextualize learning and evaluation situations.

### Examples of objects, systems, products and processes related to climate change

Aerial maps and photographs	Communications satellites
Rain gauge, thermometer, barometer, anemometer, hygrometer	Waste collection and processing equipment (e.g. glass, plastic, tires)
Probes	Antipollution systems on motorized vehicles (catalytic converter)
Radar, sonar	

### Examples of objects, systems, products and processes related to drinking water

Drinking water treatment plant	Pump, valve
Salt water treatment plant	Sprinkler
Wastewater treatment plant	Meter (water consumption)
Water supply: circulation and distribution network	Bottling equipment and processes
Artesian well, watermill	Containers: tank, bottle, can, etc.
Water tower, basin	Soil irrigation systems
Tanker	Aqueduct
Hydraulic equipment	Lock, dyke

### Examples of objects, systems, products and processes related to deforestation

Dam	Street lights
Road, highway	Forestry equipment
Bridge, tunnel	Sawmill
Road signs	

## Examples of objects, systems, products and processes related to energy

### **Production**

Nuclear power plant, thermal power plant, hydraulic power plant  
Wind turbine, underwater generator  
Photovoltaic module  
Tidal power plant, ocean thermal energy plant  
Geothermal process  
Fuel cell  
Batteries and accumulators  
Generator, alternator

### **Motors, machines, etc.**

Electric motor  
Internal combustion engine, steam engine, turbine  
Cogeneration system  
Oil: wells, platform, refining processes

### **Use (applications)**

X-ray machine, magnetic resonance imaging devices, electrotherapy unit, radiotherapy unit, etc.  
Electrical prostheses  
Telecommunications devices (e.g. satellite, television, cell phone)  
Computers, computer systems  
Programmable controllers  
Aircraft, ships, vehicles  
Machine tools  
Ovens  
Surface treatments  
Household appliances (e.g. vacuum cleaner, iron, heating pad, hair dryer, microwave oven, toaster, refrigerator, dishwasher, washer, dryer)  
Lighting fixtures, electronic devices  
Heating and air conditioning systems  
Elevators  
Home automation (automatic doors, alarm and signal systems, fire safety systems, etc.)

## Examples of objects, systems, products and processes related to residual materials

### **Air**

Pollutant analyzers: passive diffusion tube, quartz microbalance, beta radiation detector  
UV photometric measurement, infrared correlation  
Chromatographs  
Gravimeter, barometer, hygrometer, anemometer  
Ventilation devices (air exchanger)  
Humidifier, dehumidifier  
Processes for obtaining biofuels (oleaginous, ethyl, gaseous, solid)  
Particle filters, antipollution systems on motor vehicles  
Electric vehicles, hybrid vehicles

### **Water**

Sewage disposal system  
Wastewater treatment plant, wastewater purification processes (lagooning or natural filtration using microorganisms)

Drinking water treatment plant, drinking water purification processes (e.g. filtration, boiling, distillation, photo-oxidation)  
Rain gauge  
Maps of the rainwater collection system  
Canal, gate, dam, dyke, aqueduct  
Watermill, elevated tank  
Pump, water gun, sprinkler system, faucet, water softener, water meter  
Means of countering oil pollution: mobile radar remote sensing (of oil slicks on the water's surface), pumping system, pressure cleaning system, sorbent barriers, circular brush skimmer, oleophilic brush skimmer, oleophilic rollers (beach), screen (sand), mechanical rake (land)

### **Soil**

Physico-chemical depollution (dissolution of pollutants): vacuum extraction, injection, flotation treatment, etc.  
Biological depollution: processes using bacteria  
Phytoremediation (plant bioremediation)

**Examples of objects, systems, products and processes related to food production**

***Food production***

Agricultural equipment: plough, spading machine, combine, mower, sprayer, milking machine, seed drill, grinder, power loader, etc.

Drainage system, irrigation system

Fertilizer

Pesticides: insecticides, herbicides, fungicides, etc.

Antibiotics

Genetically modified organisms (GMOs)

Food processing, food preservation

Food additives: starches, sugars and sugar substitutes, food colouring, preservatives, flavourings, etc.

Food enzymes

Industrial sauces

Organic foods

***Food packaging***

Packaging materials: paper and cardboard, plastic, metal, glass, wood

Types of packaging: bags, pouches, bottles, boxes, jars, etc.

Packing processes: vacuum packing, controlled atmosphere packing, active packaging, etc.

***Waste***

Recycling equipment and facilities

Thermal waste degradation processes, biological waste degradation processes

Plastics regeneration processes, recycling processes (e.g. glass, paper)

## APPENDIX C – EXAMPLES OF LEARNING AND EVALUATION SITUATIONS

### A Power Plant on Île Beaumont

#### 1. Educational aim

This activity is intended to help students develop competencies 2 and 3, *Makes the most of his/her knowledge of science and technology* and *Communicates in the languages used in science and technology*, by carrying out a technological analysis of the operating principles of three different types of power plants and by presenting a study on the environmental impact of each type of energy production.

#### 2. Target audience

Students in the Second Year of Secondary Cycle Two (science and technology)

#### 3. Broad area of learning and focuses of development

##### *Environmental Awareness and Consumer Rights and Responsibilities*

- Knowledge of the environment (through environmental impact studies)
- Responsible consumption and use of goods and services (through a technological analysis of the power plants)
- Awareness of social, economic and ethical aspects of consumption (through the study of the population's energy needs)
- Construction of a viable environment based on sustainable development (through environmental impact studies)

#### 4. Description of the task

##### *Introduction*

The town council of Île Beaumont must replace its coal-fired power plant, which is now obsolete and causes too much pollution. The citizens do not want a nuclear power plant because of health and environmental risks. Île

Beaumont, which is accessible only by boat, is known for its fruit and vegetable production.

Three engineering firms are invited to present proposals. One of them proposes building a wind farm, another suggests a biomass power plant and the third recommends converting the existing plant to run on natural gas.

##### *Proposed activities*

Students participate in a role-playing exercise to present the operating principles and consequences of the different proposals submitted following a public call for tenders. First, the engineering firms must produce an information document in the form of a leaflet or written report, which explains in simple terms the operating principles of each type of power plant. Three teams will present the points of view of the three firms. Another team will represent the town council, whose role is to ask questions in order to select the most appropriate type of power plant.

The students must compare the environmental impact of each of the three types of production. The teacher may provide certain resources (e.g. media, IT) for the different types of power plants.

#### 5. Productions

- Information document (leaflet, poster, written report)
- Oral presentation (role-play)

## 6. Targeted subject-specific competencies

**Competency 2** – *Makes the most of his/her knowledge of science and technology*

- Puts scientific or technological issues in context
  - Consideration of the various aspects of issues when conducting environmental impact studies
- Understands the scientific principles underlying the issue
  - Development of concepts related to energy conservation, energy efficiency and chemical reactions
- Understands the technological principles underlying the issue
  - Development of concepts related to the operation of systems, constraints and innovations
- Forms an opinion about the issue
  - Consideration of the different aspects of the arguments presented

**Competency 3** – *Communicates in the languages used in science and technology*

- Participates in exchanging scientific and technological information
  - Sharing of information in order to produce an information document
- Interprets scientific and technological messages
  - Reading and analysis of documentation
- Produces and shares scientific and technological messages
  - Production of the information document and oral presentation

## 7. Cross-curricular competencies

*Uses information; Cooperates with others; Communicates appropriately; Exercises critical judgment*

## 8. Resources (specified in the program content)\*

### Compulsory concepts

The Material World	The Earth and Space
<ul style="list-style-type: none"> <li>– Combustion</li> <li>– Forms of energy</li> <li>– Energy efficiency</li> <li>– Law of conservation of energy</li> </ul>	<ul style="list-style-type: none"> <li>– Carbon cycle</li> <li>– Energy resources</li> <li>– Marine biomes</li> <li>– Terrestrial biomes</li> <li>– Greenhouse effect</li> <li>– Atmospheric circulation</li> </ul>
The Living World	The Technological World
<ul style="list-style-type: none"> <li>– Study of populations</li> <li>– Dynamics of communities</li> <li>– Dynamics of ecosystems</li> </ul>	<ul style="list-style-type: none"> <li>– Transformation of energy (electricity and magnetism)</li> <li>– Motion transmission systems</li> <li>– Orthogonal projection</li> <li>– Standards and representations (diagrams)</li> </ul>

### Methods

- Technological analysis (operating principle of the power plants)
- Formation of an opinion (consideration of different points of view, selection of criteria, organization and interpretation of documentary resources)

## 9. Approximate duration

- Eight 75-minute periods (excluding research)

## 10. Avenues for evaluation

- Evaluation of the information document (teacher)
- Joint (teacher-student) evaluation of the oral presentation
- Self-evaluation rubric for each student

\* Other resources presented in the program content (e.g. strategies, attitudes, techniques) can also be taken into consideration.

## Fishing Stories

### 1. Educational aim

This activity is intended to help students develop competencies 1 and 3, *Seeks answers or solutions to scientific or technological problems* and *Communicates in the languages used in science and technology*, by developing a decontamination plan for an acidified lake.

### 2. Target audience

Students in the Environmental Science and Technology program

### 3. Broad area of learning and focuses of development

#### *Environmental Awareness and Consumer Rights and Responsibilities*

- Knowledge of the environment (through environmental impact studies)
- Construction of a viable environment based on sustainable development (by solving an environmental problem)

### 4. Description of the task

#### *Introduction*

Your uncle owns two outfitting operations. The first is in Abitibi, on the shores of Lac Long, about 20 km away from an ore processing plant. The second is on the shores of Lac Court in the Montérégie, about 50 km from Montréal.

In recent years, there have been fewer and fewer fish in Abitibi. Your uncle wants you to use your knowledge of environmental science to determine the problem at Lac Long and to solve it in order to restore the fish population.

The following table gives a few characteristics of the two lakes:

Characteristics	Lac Long	Lac Court
Region	Abitibi	Montérégie
Volume of water	124 x 108 m <sup>3</sup>	1.21 x 108 m <sup>3</sup>
Annual precipitation	914 mm	975 mm
Bank works	None (natural)	None (natural)
Number of fishers/year	970	1360
pH of water in 1986	6.5	6.6
pH of water in 2006	5.5	6.5

Your uncle asks you to:

- determine by experiment one of the factors that might explain this situation
- propose a short-term plan for the decontamination of Lac Long based on the results of your experiments

Your solution should have as little negative impact on the lake's flora and fauna as possible.

#### *Proposed activities*

First, the students must do experiments to determine one of the factors that makes it possible for lakes to maintain a normal acidity level. To this end, they identify the variables and develop and carry out a protocol.

Second, based on their results, they develop, qualitatively and quantitatively, a plan to neutralize the acidity of the lake. They transpose the selected treatment to the appropriate scale and theoretically evaluate the toxicity of their solution.

A few lectures may be necessary to help students understand and integrate the concepts used.

A comparative study of the chosen solution and other, long-term options could be done, perhaps followed by the development of a position statement. This suggestion is aimed at helping students develop Competency 2, *Makes the most of his/her knowledge of science and technology.*

### 5. Productions

- Partial lab report (manipulations, results and interpretation of results)
- Full lab report, a condensed toxicity balance sheet and a decontamination plan

### 6. Targeted subject-specific competencies

**Competency 1** – *Seeks answers or solutions to scientific or technological problems*

- Defines a problem
  - Development or association of concepts; formulation of hypotheses
- Develops a plan of action
  - Selection and control of variables; choice of method, products and tools needed
- Carries out the procedure
  - Experimental study of the effect of an acid solution on different types of soil; verification and measurement of the effect of a given base on an acid solution
- Analyzes his/her results or solution
  - Processing of data; transposition from experimental to actual scale; evaluation of the feasibility of the proposed solution

**Competency 3** – *Communicates in the languages used in science and technology*

- Participates in exchanging scientific and technological information
  - Discussions to suggest possible plans of action; sharing of information in order to produce the required reports
- Interprets scientific and technological messages

- Reading and analysis of documentation
- Produces and shares scientific and technological messages
  - Production of lab reports, the toxicity balance sheet and the decontamination plan

### 7. Cross-curricular competencies

*Exercises critical judgment; Uses information; Communicates appropriately; Cooperates with others*

### 8. Resources (specified in the program content)\*

#### Compulsory concepts

The Material World	The Earth and Space
<ul style="list-style-type: none"> <li>– Concentration (mole/L)</li> <li>– Electrolytes</li> <li>– pH scale</li> <li>– Electrolytic dissociation</li> <li>– Ions</li> <li>– Acid-base neutralization reaction</li> <li>– Salts</li> <li>– Balancing chemical equations</li> <li>– Law of conservation of mass</li> <li>– Stoichiometry</li> <li>– Types of bonds                             <ul style="list-style-type: none"> <li>• Ionic</li> </ul> </li> <li>– Nomenclature and notation rules</li> <li>– Polyatomic ions</li> <li>– Concept of mole</li> </ul>	<ul style="list-style-type: none"> <li>– Marine biomes</li> <li>– Buffering capacity of the soil</li> <li>– Contamination</li> <li>– Atmospheric circulation                             <ul style="list-style-type: none"> <li>• Prevailing winds</li> </ul> </li> </ul>
	The Living World
	<ul style="list-style-type: none"> <li>– Dynamics of communities                             <ul style="list-style-type: none"> <li>• Biodiversity</li> <li>• Disturbances</li> </ul> </li> <li>– Ecotoxicology                             <ul style="list-style-type: none"> <li>• Contaminants</li> </ul> </li> </ul>

#### Method

- Experimental method (selection and control of variables)

\* Other resources presented in the program content (e.g. strategies, attitudes, techniques) can also be taken into consideration.

### 9. Approximate duration

- Eight 75-minute periods (excluding research)

### 10. Avenues for evaluation

- Evaluation of the partial report (teacher)
- Evaluation of the full report (teacher)
- Self-evaluation rubric for each student

## APPENDIX D – DISTRIBUTION OF COMPULSORY CONCEPTS, SECONDARY CYCLES ONE AND TWO

### General Education Path THE MATERIAL WORLD

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
<p><b>Properties</b></p> <ul style="list-style-type: none"> <li>– Characteristic properties</li> <li>– Mass</li> <li>– Volume</li> <li>– Temperature</li> <li>– States of matter</li> <li>– Acidity/alkalinity</li> </ul>	<p><b>Properties of matter</b></p> <ul style="list-style-type: none"> <li>– Characteristic physical properties                             <ul style="list-style-type: none"> <li>• Melting point</li> <li>• Boiling point</li> <li>• Density</li> <li>• Solubility</li> </ul> </li> <li>– Characteristic chemical properties                             <ul style="list-style-type: none"> <li>• Reaction to indicators</li> </ul> </li> <li>– Properties of solutions                             <ul style="list-style-type: none"> <li>• Concentration (% g/L)</li> <li>• Solute</li> <li>• Solvent</li> </ul> </li> </ul>	<p><b>Physical properties of solutions</b></p> <ul style="list-style-type: none"> <li>– Concentration (ppm)</li> <li>– Electrolytes</li> <li>– pH scale</li> <li>– Electrolytic dissociation</li> <li>– Ions</li> <li>– Electrical conductivity</li> </ul>	<p><b>Physical properties of solutions</b></p> <ul style="list-style-type: none"> <li>– <u>Concentration (ppm, mole/L)</u></li> <li>– <u>Strength of electrolytes</u></li> </ul>
<p><b>Changes</b></p> <ul style="list-style-type: none"> <li>– Physical change</li> <li>– Chemical change</li> <li>– Conservation of matter</li> <li>– Mixtures</li> <li>– Solutions</li> <li>– Separation of mixtures</li> </ul>	<p><b>Changes in matter</b></p> <ul style="list-style-type: none"> <li>– Physical changes                             <ul style="list-style-type: none"> <li>• Dissolution</li> <li>• Dilution</li> <li>• Phase changes</li> </ul> </li> <li>– Chemical changes                             <ul style="list-style-type: none"> <li>• Decomposition and synthesis</li> <li>• Oxidation</li> <li>• Precipitation</li> </ul> </li> <li>– Forms of energy (chemical, thermal, mechanical, radiation)</li> <li>– Particle model</li> </ul>	<p><b>Chemical changes</b></p> <ul style="list-style-type: none"> <li>– Combustion</li> <li>– Photosynthesis and respiration</li> <li>– Acid-base neutralization reaction</li> <li>– Balancing chemical equations</li> <li>– Law of conservation of mass</li> </ul>	<p><b>Chemical changes</b></p> <ul style="list-style-type: none"> <li>– <u>Salts</u></li> <li>– <u>Stoichiometry</u></li> <li>– <u>Types of bonds</u> <ul style="list-style-type: none"> <li>• <u>Covalent</u></li> <li>• <u>Ionic</u></li> </ul> </li> <li>– <u>Endothermic and exothermic reactions</u></li> </ul>
			<p><b>Nuclear transformations</b></p> <ul style="list-style-type: none"> <li>– <u>Nuclear stability</u></li> <li>– <u>Radioactivity</u></li> <li>– <u>Fission and fusion</u></li> </ul>

## THE MATERIAL WORLD (CONT.)

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
<p><b>Organization</b></p> <ul style="list-style-type: none"> <li>– Atom</li> <li>– Element</li> <li>– Periodic table</li> <li>– Molecule</li> </ul>	<p><b>Organization of matter</b></p> <ul style="list-style-type: none"> <li>– Pure substance (compound, element)</li> <li>– Homogeneous and heterogeneous mixtures</li> </ul>		<p><b>Organization of matter</b></p> <ul style="list-style-type: none"> <li>– Rutherford-Bohr atomic model</li> <li>– Lewis notation</li> <li>– Families and periods of the periodic table</li> </ul>
			<p><b>Organization of matter</b></p> <ul style="list-style-type: none"> <li>– <u>Neutron</u></li> <li>– <u>Simplified atomic model</u></li> <li>– <u>Nomenclature and notation rules</u></li> <li>– <u>Polyatomic ions</u></li> <li>– <u>Concept of mole</u></li> <li>– <u>Avogadro's number</u></li> </ul>
			<p><b>Periodic table</b></p> <ul style="list-style-type: none"> <li>– <u>Relative atomic mass</u></li> <li>– <u>Atomic number</u></li> <li>– <u>Periodicity of properties</u></li> <li>– <u>Isotopes</u></li> </ul>
	<p><b>Fluids</b></p> <ul style="list-style-type: none"> <li>– Compressible and incompressible fluids</li> <li>– Pressure</li> <li>– Relationship between pressure and volume</li> </ul>	<p><b>Electricity and electromagnetism</b></p> <p><b>Electricity</b></p> <ul style="list-style-type: none"> <li>– Electrical charge</li> <li>– Static electricity</li> <li>– Ohm's law</li> <li>– Electrical circuits</li> <li>– Relationship between power and electrical energy</li> </ul> <p><b>Electromagnetism</b></p> <ul style="list-style-type: none"> <li>– Forces of attraction and repulsion</li> <li>– Magnetic field of a live wire</li> </ul>	<p><b>Electricity and electromagnetism</b></p> <p><b>Electricity</b></p> <ul style="list-style-type: none"> <li>– <u>Kirchhoff's laws</u></li> <li>– <u>Electrical field</u></li> <li>– <u>Coulomb's law</u></li> </ul> <p><b>Electromagnetism</b></p> <ul style="list-style-type: none"> <li>– <u>Magnetic field of a solenoid</u></li> </ul>
			<p><b>Transformation of energy</b></p> <ul style="list-style-type: none"> <li>– Law of conservation of energy</li> <li>– Energy efficiency</li> <li>– Distinction between heat and temperature</li> </ul>
			<p><b>Transformation of energy</b></p> <ul style="list-style-type: none"> <li>– <u>Relationship between heat energy, specific heat capacity, mass and temperature variations</u></li> <li>– <u>Relationship between work, force and travel</u></li> <li>– <u>Effective force</u></li> <li>– <u>Relationship between work and energy</u></li> <li>– <u>Relationship between potential energy, mass, acceleration and travel</u></li> <li>– <u>Relationship between mass and weight</u></li> <li>– <u>Relationship between kinetic energy, mass and velocity</u></li> </ul>

## THE MATERIAL WORLD (CONT.)

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
	<p><b>Waves</b></p> <ul style="list-style-type: none"> <li>– Frequency</li> <li>– Wavelength</li> <li>– Amplitude</li> <li>– Decibel scale</li> <li>– Electromagnetic spectrum</li> <li>– Deviation of light waves</li> <li>– Focal point of a lens</li> </ul>		

## LIVING WORLD

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
<p><b>Diversity of life forms</b></p> <ul style="list-style-type: none"> <li>– Habitat</li> <li>– Ecological niche</li> <li>– Species</li> <li>– Population</li> <li>– Physical and behavioural adaptation</li> <li>– Evolution</li> <li>– Taxonomy</li> <li>– Genes and chromosomes</li> </ul>	<p><b>Cell division</b></p> <ul style="list-style-type: none"> <li>– DNA</li> <li>– Mitosis</li> <li>– Functions of cell division (reproduction, growth, regeneration)</li> <li>– Meiosis and sexual development (meiosis, fertilization)</li> <li>– Genetic diversity</li> </ul>	<p><b>Ecology</b></p> <ul style="list-style-type: none"> <li>– Study of populations (density, biological cycles)</li> <li>– Dynamics of communities                             <ul style="list-style-type: none"> <li>• Biodiversity</li> <li>• Disturbances</li> </ul> </li> <li>– Dynamics of ecosystems                             <ul style="list-style-type: none"> <li>• Trophic relationships</li> </ul> </li> <li>• Primary productivity                             <ul style="list-style-type: none"> <li>• Material and energy flow</li> <li>• Chemical recycling</li> </ul> </li> </ul>	<p><b>Ecology</b></p> <ul style="list-style-type: none"> <li>– <u>Ecological footprint</u></li> <li>– <u>Ecotoxicology</u> <ul style="list-style-type: none"> <li>• <u>Contaminant</u></li> <li>• <u>Bioconcentration</u></li> <li>• <u>Bioaccumulation</u></li> <li>• <u>Toxicity level</u></li> </ul> </li> </ul>
<p><b>Survival of species</b></p> <ul style="list-style-type: none"> <li>– Asexual and sexual reproduction</li> <li>– Reproductive mechanisms in plants</li> <li>– Reproductive mechanisms in animals</li> <li>– Reproductive organs</li> <li>– Gametes</li> <li>– Fertilization</li> <li>– Pregnancy</li> <li>– Stages of human development</li> <li>– Contraception</li> <li>– Methods of preventing the implantation of the zygote in the uterus</li> <li>– Sexually transmitted diseases</li> </ul>	<p><b>Tissues, organs and systems</b></p> <ul style="list-style-type: none"> <li>– Tissues</li> <li>– Organs</li> <li>– Systems</li> </ul>		<p><b>Genetics</b></p> <ul style="list-style-type: none"> <li>– <u>Heredity</u></li> <li>– <u>Gene</u></li> <li>– <u>Allele</u></li> <li>– <u>Character trait</u></li> <li>– <u>Genotype and phenotype</u></li> <li>– <u>Homozygote and heterozygote</u></li> <li>– <u>Dominance and recessivity</u></li> <li>– <u>Cross-breeding</u></li> <li>– <u>Protein synthesis</u></li> </ul>
<p><b>Life-sustaining processes</b></p> <ul style="list-style-type: none"> <li>– Characteristics of living things</li> <li>– Plant and animal cells</li> <li>– Photosynthesis and respiration</li> <li>– Cellular components visible under a microscope</li> <li>– Inputs and outputs (energy, nutrients, waste)</li> <li>– Osmosis and diffusion</li> </ul>	<p style="text-align: center;"><b>SYSTEMS NUTRITION</b></p> <p><b>Digestive system</b></p> <ul style="list-style-type: none"> <li>– Types of food (water, proteins, carbohydrates, fats, vitamins, minerals)</li> <li>– Energy value of different foods</li> <li>– Digestive tract (mouth, esophagus, stomach, small intestine, large intestine, anus)</li> <li>– Transformation of food (mechanical, chemical)</li> <li>– Digestive glands (salivary glands, gastric glands, pancreas, liver, intestinal glands)</li> </ul>		

## LIVING WORLD (CONT.)

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
	<p><b>Circulatory and respiratory systems</b></p> <ul style="list-style-type: none"> <li>– Respiratory system (nasal cavity, pharynx, trachea, bronchi, lungs)</li> <li>– Functions of blood constituents (plasma, formed elements)</li> <li>– Compatibility of blood types</li> <li>– Circulatory system (types of blood vessels)</li> <li>– Lymphatic system (lymph, antibodies)</li> </ul> <p><b>Excretory system</b></p> <ul style="list-style-type: none"> <li>– Urinary system (kidneys, ureters, bladder, urethra)</li> <li>– Components of urine (water, mineral salts, urea)</li> <li>– Maintaining a balanced metabolism (kidneys, lungs, sweat glands)</li> </ul>		
	<p style="text-align: center;"><b>RELATIONSHIPS</b></p> <p><b>Nervous and musculoskeletal systems</b></p> <ul style="list-style-type: none"> <li>– Central nervous system (brain, spinal cord)</li> <li>– Peripheral nervous system (nerves)                             <ul style="list-style-type: none"> <li>• Neuron (synapse, axon, dendrites)</li> <li>• Neural inflow (voluntary act, reflex arc)</li> </ul> </li> <li>– Sensory receptors (eye, ear, skin, tongue, nose)</li> </ul> <p><b>Musculoskeletal system (bones, joints, muscles)</b></p> <ul style="list-style-type: none"> <li>• Function of bones, joints and muscles</li> <li>• Types of muscles</li> <li>• Types of joint movements</li> </ul>		
	<p style="text-align: center;"><b>REPRODUCTION</b></p> <p><b>Reproductive system</b></p> <ul style="list-style-type: none"> <li>– Puberty (male and female)</li> <li>– Hormone regulation in men                             <ul style="list-style-type: none"> <li>• Spermatogenesis</li> <li>• Erection</li> <li>• Ejaculation</li> </ul> </li> <li>– Hormone regulation in women                             <ul style="list-style-type: none"> <li>• Oogenesis</li> <li>• Ovarian cycle</li> <li>• Menstrual cycle</li> </ul> </li> </ul>		

## THE EARTH AND SPACE

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
<p><b>General characteristics of the Earth</b></p> <ul style="list-style-type: none"> <li>– Internal structure of the Earth</li> <li>– Lithosphere</li> <li>– Hydrosphere</li> <li>– Atmosphere</li> <li>– Types of rocks (basic minerals)</li> <li>– Atmospheric layers</li> <li>– Water (distribution)</li> <li>– Air (composition)</li> <li>– Types of soil</li> <li>– Relief</li> </ul>	<p><b>The Earth</b></p> <ul style="list-style-type: none"> <li>– Geological time scale</li> <li>– Major stages in the history of life on Earth</li> <li>– Extinctions</li> <li>– Fossils</li> <li>– Stratigraphic layers</li> </ul>	<p><b>The Earth</b></p> <p><b>Biogeochemical cycles</b></p> <ul style="list-style-type: none"> <li>– Carbon cycle</li> <li>– Nitrogen cycle</li> </ul>	<p><b>The Earth</b></p> <ul style="list-style-type: none"> <li>– <u>Phosphorus cycle</u></li> </ul>
		<p><b>Climate zones</b></p> <ul style="list-style-type: none"> <li>– Factors that influence the distribution of biomes</li> <li>– Marine biomes</li> <li>– Terrestrial biomes</li> </ul>	
<p><b>Geological and geophysical phenomena</b></p> <ul style="list-style-type: none"> <li>– Tectonic plate</li> <li>– Volcano</li> <li>– Earthquake</li> <li>– Orogenesis</li> <li>– Erosion</li> <li>– Natural energy sources</li> <li>– Winds</li> <li>– Water cycle</li> <li>– Renewable and nonrenewable energy resources</li> </ul>		<p><b>Lithosphere</b></p> <ul style="list-style-type: none"> <li>– Minerals</li> <li>– Soil profile (horizons)</li> <li>– Permafrost</li> <li>– Energy resources</li> </ul>	<p><b>Lithosphere</b></p> <ul style="list-style-type: none"> <li>– <u>Soil depletion</u></li> <li>– <u>Buffering capacity of the soil</u></li> <li>– <u>Contamination</u></li> </ul>
		<p><b>Hydrosphere</b></p> <ul style="list-style-type: none"> <li>– Catchment area</li> <li>– Oceanic circulation</li> <li>– Glacier and ice floe</li> <li>– Salinity</li> <li>– Energy resources</li> </ul>	<p><b>Hydrosphere</b></p> <ul style="list-style-type: none"> <li>– <u>Contamination</u></li> <li>– <u>Eutrophication</u></li> </ul>
		<p><b>Atmosphere</b></p> <ul style="list-style-type: none"> <li>– Greenhouse effect</li> <li>– Atmospheric circulation</li> <li>– Air mass</li> <li>– Cyclone and anticyclone</li> <li>– Energy resources</li> </ul>	<p><b>Atmosphere</b></p> <ul style="list-style-type: none"> <li>– <u>Atmospheric circulation</u> <ul style="list-style-type: none"> <li>• <u>Prevailing winds</u></li> </ul> </li> <li>– <u>Contamination</u></li> <li>– <u>Ozone</u></li> </ul>

## THE EARTH AND SPACE (CONT.)

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
<p><b>Astronomical phenomena</b></p> <ul style="list-style-type: none"> <li>– Universal gravitation (qualitative study)</li> <li>– Solar system</li> <li>– Light (properties)</li> <li>– Cycles of day and night</li> <li>– Phases of the Moon</li> <li>– Eclipses</li> <li>– Seasons</li> <li>– Comets</li> <li>– Aurora borealis (northern lights)</li> <li>– Meteoroid impact</li> </ul>	<p><b>Space</b></p> <ul style="list-style-type: none"> <li>– Scale of the universe                             <ul style="list-style-type: none"> <li>• Astronomical unit</li> <li>• Light year</li> <li>• Location of the Earth in the universe</li> </ul> </li> <li>– Conditions conducive to the development of life</li> </ul>		<p><b>Space</b></p> <ul style="list-style-type: none"> <li>– Solar energy flow</li> <li>– Earth-Moon system (gravitational effect)</li> </ul>

## THE TECHNOLOGICAL WORLD

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
	<p><b>Graphical language</b></p> <ul style="list-style-type: none"> <li>– Geometric lines</li> <li>– Types of representation (sketch, perspective drawing, oblique projection)</li> <li>– Basic lines</li> <li>– Scales</li> <li>– Orthogonal projections (multiview, isometric)</li> <li>– Sections</li> <li>– Dimensioning</li> <li>– Standards and representations (diagrams and symbols)</li> </ul>		<p><b>Graphical language</b></p> <ul style="list-style-type: none"> <li>– Axonometric projection: exploded view (reading)</li> <li>– Multiview orthogonal projection (assembly drawing)</li> <li>– Dimensional tolerances</li> </ul>
<p><b>Engineering</b></p> <ul style="list-style-type: none"> <li>– Specifications</li> <li>– Design plan</li> <li>– Technical drawing</li> <li>– Manufacturing process sheet</li> <li>– Raw material</li> <li>– Material</li> <li>– Equipment</li> </ul>	<p><b>Mechanical engineering</b></p> <ul style="list-style-type: none"> <li>– Linking of mechanical parts</li> <li>– Typical functions</li> <li>– Function, components and use of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)</li> <li>– Function, components and use of motion transformation systems (screw gear system, cams, connecting rods, cranks, slides, rotating slider crank mechanisms, rack-and-pinion drive)</li> </ul>	<p><b>Mechanical engineering</b></p> <ul style="list-style-type: none"> <li>– Characteristics of linking of mechanical parts</li> <li>– Guiding controls</li> <li>– Construction and characteristics of motion transmission systems (gear wheels, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)</li> <li>– Speed changes</li> <li>– Construction and characteristics of motion transformation systems (screw gear system, cams, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive)</li> </ul>	<p><b>Mechanical engineering</b></p> <ul style="list-style-type: none"> <li>– Adhesion and friction between parts</li> <li>– Degree of freedom of a part</li> <li>– Construction and characteristics of motion transformation systems (screw gear system, connecting rods, cranks, slides, rotating slider crank mechanism, rack-and-pinion drive, eccentrics)</li> </ul>
<p><b>Technological systems</b></p> <ul style="list-style-type: none"> <li>– System (overall function, inputs, processes, outputs, control)</li> <li>– Components of a system</li> <li>– Basic mechanical functions (links, guiding control)</li> <li>– Energy transformations</li> </ul>		<p><b>Electrical engineering</b></p> <ul style="list-style-type: none"> <li>– Power supply</li> <li>– Conduction, insulation and protection</li> <li>– Control</li> <li>– Transformation of energy (electricity and light, heat, vibration, magnetism)</li> </ul>	<p><b>Electrical engineering</b></p> <ul style="list-style-type: none"> <li>– Conduction, insulation and protection (<u>resistance and coding, printed circuit</u>)</li> <li>– Typical controls (<u>lever, toggle, unipolar, bipolar, unidirectional, bidirectional</u>)</li> </ul>
<p><b>Forces and motion</b></p> <ul style="list-style-type: none"> <li>– Types of motion</li> <li>– Effects of a force</li> <li>– Simple machines</li> <li>– Mechanisms that transmit motion</li> <li>– Mechanisms that bring about a change in motion</li> </ul>	<p><b>Materials</b></p> <ul style="list-style-type: none"> <li>– Constraints (tension, compression, torsion)</li> <li>– Mechanical properties</li> <li>– Types and properties                             <ul style="list-style-type: none"> <li>• Ferrous alloys</li> <li>• Nonferrous metals and alloys</li> <li>• Wood and modified wood</li> </ul> </li> </ul>	<p><b>Materials</b></p> <ul style="list-style-type: none"> <li>– Constraints (deflection, shearing)</li> <li>– Characteristics of mechanical properties</li> <li>– Types and properties                             <ul style="list-style-type: none"> <li>• Plastics (thermoplastics, thermosetting plastics)</li> <li>• Ceramics</li> <li>• Composites</li> </ul> </li> <li>– Modification of properties (degradation, protection)</li> </ul>	<p><b>Materials</b></p> <ul style="list-style-type: none"> <li>– <u>Heat treatments</u></li> </ul>

## THE TECHNOLOGICAL WORLD (CONT.)

Cycle One	Cycle Two (Basic Program)		Cycle Two (Optional Program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV
Science and Technology	Science and Technology		Environmental Science and Technology
			<p><b>Manufacturing</b></p> <ul style="list-style-type: none"> <li>– <u>Shaping</u> <ul style="list-style-type: none"> <li>• Machines and tools</li> </ul> </li> <li>– <u>Manufacturing</u> <ul style="list-style-type: none"> <li>• Characteristics of laying out, drilling, tapping and threading</li> </ul> </li> <li>– <u>Measurements</u> <ul style="list-style-type: none"> <li>• Direct measurement (vernier calipers)</li> </ul> </li> </ul>
	<p><b>Biotechnology</b></p> <ul style="list-style-type: none"> <li>– Processes                             <ul style="list-style-type: none"> <li>• Pasteurization</li> <li>• Manufacture of vaccines</li> <li>• Assisted reproduction</li> <li>• Cell cultures</li> <li>• Genetic transformation (GMOs)</li> </ul> </li> </ul>		<p><b>Biotechnology</b></p> <ul style="list-style-type: none"> <li>– <u>Cloning</u></li> <li>– <u>Wastewater treatment</u></li> <li>– <u>Biodegradation of pollutants</u></li> </ul>

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