INTRODUCTION

Background

This document presents student learning outcomes for Senior 3 Current Topics in the Sciences. These learning outcomes are the same for students in the English, French Immersion, and Français Programs and result from a partnership involving two divisions of Manitoba Education, Citizenship and Youth: School Programs and Bureau de l'éducation française. Manitoba's science student learning outcomes are based on those found within the *Common Framework of Science Learning Outcomes K to 12: Pan-Canadian Protocol for Collaboration on School Curriculum* (Council of Ministers of Education, Canada). The latter, commonly referred to as the *Pan-Canadian Science Framework*, was initiated under the Pan-Canadian Protocol for Collaboration on School Curriculum (1995). It was developed by educators from Manitoba, British Columbia, Saskatchewan, Alberta, the Northwest Territories, the Yukon Territory, Ontario, and the Atlantic Provinces.

> Student learning outcomes are concise descriptions of the knowledge and skills [and attitudes] that students are expected to learn in a course or grade in a subject area (Manitoba Education and Training, *A Foundation for Excellence* 14).

Senior 3 Current Topics in the Sciences: A Foundation for Implementation provides the basis for learning, teaching, and assessing science in a topical and interdisciplinary manner. The document provides teachers with support in implementation, including suggestions for unit development, instruction, and assessment. It also serves as the starting point for the development of support materials, including expanded units, learning resources, assessment tools, and professional development for teachers.

Goals for Canadian Science Education

Several goals promoting scientific literacy within Canadian science education were developed as part of *Pan-Canadian Science Framework*, and are addressed through Manitoba science curricula. It is hoped that science education will

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

Vision for Scientific Literacy

Scientific literacy includes the ability to recognize connections within science, mathematics and technology; understand important scientific concepts; be familiar with the natural world, recognizing its diversity and unity; demonstrate environmental responsibility; and use scientific knowledge and ways of thinking for individual and social purposes, developing solutions to local and global problems (Hodson, “Toward Universal Scientific Literacy” 13).

Factors such as global interdependence, rapid scientific and technological innovation, the need for a sustainable environment, economy, and society, and the pervasiveness of science and technology in daily life reinforce the importance of scientific literacy. Scientifically, literate individuals can more effectively interpret information, solve problems, make informed decisions, accommodate change, and achieve new understandings. Science education makes possible the development of scientific literacy and helps build stronger futures for Canada’s young people.

Senior 3 Current Topics in the Sciences supports and promotes the vision of scientific literacy as articulated in the *Pan-Canadian Science Framework* (Council of Ministers of Education, Canada).

> The [*Pan-Canadian Science Framework*] is guided by the vision that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them.
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> Diverse learning experiences based on the [*Pan-Canadian Science Framework*] will provide students with many opportunities to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, their careers, and their future (Council of Ministers of Education, Canada 4).

Development of scientific literacy is supported by instructional environments that engage students in the following processes:

- **Scientific inquiry:** Students address questions about natural phenomena, involving broad explorations as well as focused investigations.
- **Technological problem solving (design process):** Students seek answers to practical problems requiring the application of their science knowledge in various ways.
- **Decision making:** Students identify issues and pursue science knowledge that will inform their decisions.

Through these processes, students discover the significance of science in their lives and come to appreciate the interrelatedness of science, technology, society, and the environment.

Each of these processes can be a starting point for science learning, and may encompass the exploration of new ideas, the development of specific investigations, and the application of ideas that are learned.

To achieve the vision of scientific literacy, students must become increasingly engaged in the planning, development, and evaluation of their own learning experiences. They should have opportunities to work cooperatively with other students, to initiate investigations, to communicate their findings, and to complete projects that demonstrate their learning.

When beginning the design of a unit, teachers and students should identify expected student learning outcomes and establish performance criteria. It is important that these criteria correspond with provincial learning outcomes. This communication between students and teachers helps to identify clearly what needs to be accomplished, thereby assisting in the learning process.

When students are aware of expected learning outcomes, they will be more focused on learning and more likely to assess their own progress. Furthermore, they can participate in creating appropriate assessment and evaluation criteria. Assessment methods must be valid, reliable, and fair to students.

Beliefs about Learning, Teaching, and Assessing Science

Promoting scientific literacy for future citizens requires an understanding of how students learn, how science can best be taught, and how learning can be assessed.

> Learning in science is fundamental to understanding the world in which we live and work. It helps people to clarify ideas, to ask questions, to test explanations through measurement and observation, and to use their findings to establish the worth of an idea (New Zealand Ministry of Education 7).

Students are curious, active learners who have individual interests, abilities, and needs. They come to school with various personal and cultural experiences and prior knowledge that generate a range of attitudes and beliefs about science and life.

Students learn most effectively when their study of science is rooted in concrete learning experiences related to a particular context or situation, and applied to their world where appropriate. Ideas and understandings that students develop should be progressively extended and reconstructed as students grow in their experiences and in their ability to conceptualize. Learning involves the process of linking newly constructed understandings with prior knowledge and adding new contexts and experiences to current understandings.

> …the ever-growing importance of scientific issues in our daily lives demands a populace who have sufficient knowledge and understanding to follow science and scientific debates with interest, and to engage with the issues science and technology poses—both for them individually, and for our society as a whole (Millar and Osborne 1).

Conceptual Learning in Science

Students come from a variety of backgrounds and have distinct learning requirements, learning and thinking approaches, and prior knowledge and experiences. Their depth of prior knowledge varies, reflecting their experiences inside and outside the classroom. Students form views and ideas about the natural world long before they receive formal instruction. Some entry-level knowledge held by students may be limited or incorrect and may impede new learning.

> Students don't come to the science classroom empty-headed but arrive with lots of strongly formed ideas about how the natural world works. Many believe, for example, that some materials (such as wool) are intrinsically warm, whereas others (such as metal) are cold by nature. These misconceptions are held tenaciously, even in the face of formal science instruction to the contrary (Raizen and Kaser 719).

For new learning to occur, it is important for teachers to acknowledge and activate prior knowledge, recognize misconceptions, and encourage students to relate new information to prior experiences.

> Conceptual change, as we currently conceive it, involves the learner recognizing his/her existing ideas and beliefs, evaluating these ideas and beliefs (preferably in terms of what is to be learned and how this is to be learned), and then personally deciding whether or not to reconstruct these existing ideas and beliefs (Gunstone 132).

Misconceptions often form the basis upon which further concept development takes place. The processes by which students come to recognize that certain ideas are not supported by current evidence and subsequently construct new representations is critical to learning. Students' theories may be emerging and amenable to change or well entrenched and very difficult to change. Some misconceptions may persist despite instruction to the contrary.

As students progress in their understanding of science, they will move closer to the current scientific understanding of the phenomena being studied. In so doing, they may gain a deeper understanding of the nature of the knowledge they have acquired and the nature of the thought processes that made such development possible (Murray).

> Good learning incorporates linking, and good teaching promotes it. Even better learning follows when students comprehend why links are important, and actively seek them for themselves between topics and across subjects (Fensham, Gunstone, and White 7).

Developing conceptually coherent links between new information or concepts and prior knowledge increases the likelihood that a new idea will be accepted and integrated into an existing cognitive structure, thus connecting and enduring in students' minds (Biological Sciences Curriculum Study [BSCS]; Driver and Oldham).

Some studies suggest that many adolescents prefer most concepts at a concrete level, with achievement in science depending more on specific abilities and prior experience than cognitive stage (Driver and Easley). The context and content of a problem-solving situation are important to the learning of specific conceptual skills.

Students’ conceptions of the nature of science may not be coherent nor consistent, and may be significantly influenced by teachers’ presentations of subject matter. Teachers’ views may be influenced by experience and subject matter, and may not necessarily be congruent with actions in the classroom (Monk and Dillon). According to Driver and Oldham the teacher “facilitates conceptual change by encouraging pupils to engage actively in the personal construction of meaning” (62) and provides mechanisms for appropriate feedback.

> When instruction is anchored in the context of the learner’s world, students are more likely to take ownership and determine the direction for their learning (Sutton and Krueger 7).

Manitoba’s cultural diversity provides opportunities for linking a wealth of culturally significant references and learning resources to science learning. Students from various backgrounds bring socially constructed meanings, references, and values to science learning experiences, as well as their unique learning approaches. As noted in *Senior Years Science Teacher’s Handbook* (hereafter referred to as *SYSTH*), “To be effective, the classroom must reflect, accommodate, and embrace the cultural diversity of its students” (Manitoba Education and Training 7.13).

Teachers are encouraged to relate the natural habitats of surrounding communities to particular science learning outcomes. The careful selection of learning resources that acknowledge cultural, racial, and gender differences will allow students to affirm and strengthen their unique social, cultural, and individual identities. To provide a meaningful learning environment for all requires that teachers be sensitive to the diverse backgrounds and experiences represented in the Senior Years classroom.

Integrating the Sciences

Educational discussions on teaching the sciences using an integrated approach have been occurring since the early 1900s. By the 1970s many examples of blended instruction were evident but the idea of making science meaningful by teaching the disciplines in a connected and context-rich fashion began to gain compelling prominence in the late 1980s (McComas and Wang).

Science instruction that addresses the main ideas of science and the interrelatedness of the various phenomena within the disciplines will provide a greater depth of understanding and make science more meaningful (U.S. Department of Education 1). A growing number of careers require a strong and broad foundation in science. Secondary science courses promote the development of practical skills, the processes and methods of science, a knowledge of scientific concepts, an appreciation of the complex relationships between science, society, and the environment, as well as fostering positive attitudes towards science (Driver and Oldham; Hodson). An integrated science course is a valuable and viable alternative to regular secondary science courses because it engages a greater diversity of students, reflects the unifying concepts and principles of science, reflects the reality of the natural world, and may better prepare students to think comprehensively about an increasingly complex world (BSCS; Willis).

> The world around us is changing rapidly. There have been changes in how people live, work, and learn. Likewise, the culture and practice of science continue to evolve. Science is conducted less in bounded disciplines like physics or biology and more in transdisciplinary research fields, of which there are over 400 in the area of biology alone. The emphasis of instruction in science classrooms should be on the future (using science for solving society's dilemmas), not on the past (science taught as a history of the discipline). If the goal is to produce scientifically literate citizens who can apply scientific thinking in real-life problem-solving, then subject integration is essential (Sutton and Krueger v, 56).

An integrated approach to studying the sciences makes content more relevant and useful, motivating the development of independent, proactive, and scientifically literate learners better prepared to interact and participate in an increasingly complex and interrelated world (BSCS; Relan and Kimpston 2). Connecting subject areas through interdisciplinary instruction allows students to relate their learning to the real world and become actively involved as decision makers and problem solvers in their own education (Drake; Fogarty, "Ten Ways to Integrate Curriculum"; Relan and Kimpston; Willis).

A unified approach can lend coherence to facts by showing how they interrelate and use this unity of knowledge to view problems from several perspectives. Students learn how disciplines work together and get a broader view of the subject matter of each, recognizing the significance of the various disciplines and cross-referencing between them (Lewko and McCorquodale; Willis).

Recent brain research indicates that interdisciplinary teaching and learning allows students to assimilate, learn, retain, and apply knowledge more effectively (Palmer; Relan and Kimpston; Willis). The brain searches for patterns and interconnections as a way of making meaning (Drake). Information that is multiply connected and presented in a meaningful context is better understood and remembered (Shoemaker; Sutton and Krueger).

A conceptually coherent science program that integrates content knowledge across discipline boundaries provides substantive opportunities for learning for a broad range of students (BSCS). Broad themes and unifying principles provide a rich context and a creative learning environment, motivating students to learn by establishing meaningful and relevant connections, enhancing the acquisition of higher-order thinking skills, and providing students with the confidence to become involved in the scientific and technological issues important to their world (Andrade; BSCS; Shanahan, Robinson, and Scheider).

Instructional Design: Promoting Changing Emphases

This curriculum document provides the framework for planning and developing thematic units in Senior 3 Current Topics in the Sciences. Each topic selected and developed as a unit of study should address a number of the specific learning outcomes (SLOs), as derived from the four general learning outcomes (GLOs) (see Appendix 1 for an SLO Tracking Chart). By the end of the course of study, the student will have encountered, and will have had adequate opportunity to achieve, each of the SLOs at least once. Some SLOs—due in part to the manner in which these are addressed—may require treatment across more than one unit in the course in order to be adequately accomplished.

Multidisciplinary topics based on current issues serve as the organizing themes for this curriculum, in which scientific knowledge and its implications are presented in a unified manner, integrating the areas of biology, chemistry, physics, and geosciences. The curriculum shifts the focus from teaching concepts and facts to teaching critical thinking and problem-solving skills developed through the study of a particular topic, from which key concepts and facts will evolve.

This document is based on the philosophy that all students can learn science and should be provided with the opportunity to do so. The integrated science approach responds to the diversity among students, and recognizes that "different students will achieve understanding in different ways, and different students will achieve different degrees of depth and breadth of understanding depending on interest, ability, and context" (National Research Council 2).

> "Chance favors the prepared mind," and a prepared mind is an open one. In the integrated science experience, this is a major operating principle for students, teachers, and administrators. Be prepared to see things differently, respond to situations differently, respond to questions differently, respond to content differently, and respond to students differently. Being open, both with respect to the nature of the content and to the mechanics of such a program, will provide teachers, students and administrators the opportunity for improved science teaching and learning (BSCS 154).

Student learning outcomes in Senior 3 Current Topics in the Sciences encompass the following changing emphases in **science education content delivery**, as envisioned by the *National Science Education Standards* (National Research Council 113).

Changing Emphases in Science Education

Less Emphasis On		More Emphasis On
Knowing scientific facts and information	⇨	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter disciplines (physical, life, earth sciences) for their own sake	⇨	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and science process	⇨	Integrating all aspects of science content
Covering many science topics	⇨	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	⇨	Implementing inquiry as instructional strategies, abilities, and ideas to be learned

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Student learning outcomes in Senior 3 Current Topics in the Sciences also encompass changing emphases to promote **inquiry**, as envisioned by the *National Science Education Standards* (National Research Council 113).

Changing Emphases to Promote Inquiry

Less Emphasis On		More Emphasis on
Activities that demonstrate and verify science content	⇨	Activities that investigate and analyze science questions
Investigations confined to one class period	⇨	Investigations over extended periods of time
Process skills out of context	⇨	Process skills in context
Emphasis on individual process skills such as observation or inference	⇨	Using multiple process skills—manipulation, cognitive, procedural
Getting an answer	⇨	Using evidence and strategies for developing or revising an explanation
Science as exploration and experiment	⇨	Science as argument and explanation
Providing answers to questions about science content	⇨	Communicating science explanations
Individuals and groups of students analyzing and synthesizing data without defending a conclusion	⇨	Groups of students often analyzing and synthesizing data after defending conclusions
Doing few investigations in order to leave time to cover large amounts of content	⇨	Doing more investigations in order to develop understanding, ability, values of inquiry, and knowledge of science content
Concluding inquiries with the result of the experiment	⇨	Applying the results of experiments to scientific arguments and explanations
Management of materials and equipment	⇨	Management of ideas and information
Private communication of student ideas and conclusions to teacher	⇨	Public communication of student ideas and work to classmates

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