INTRODUCTION

Background

Senior 4 Physics: A Foundation for Implementation presents student learning outcomes for Senior 4 Physics. These learning outcomes are the same for students in English, French Immersion, Français, and Senior Years Technology Education programs, and result from a partnership involving two divisions of Manitoba Education, Citizenship and Youth: School Programs Division and Bureau de l'éducation française. Manitoba's science student learning outcomes for Senior 4 Physics are based, in part, on those within the *Common Framework of Science Learning Outcomes K to 12* (Council of Ministers of Education, Canada) and on those developed as components of the 1998 Transitional Curricula. The former, commonly referred to as the *Pan-Canadian Science Framework*, was initiated under the Pan-Canadian Protocol for Collaboration on School Curriculum (1997), and was developed by educators from Manitoba, Saskatchewan, Alberta, British Columbia, the Northwest Territories, the Yukon Territory, Ontario, and the Atlantic provinces.

Senior 4 Physics: A Foundation for Implementation provides the basis for learning, teaching, and assessing physics in Manitoba. It also serves as a starting point for future development of curriculum support documents, related teacher-support materials, learning resources, assessment tools, and professional learning for teachers. This document also complements the *Pan-Canadian Science Framework* by providing support for its implementation, including suggestions for instruction and assessment.

Vision for Scientific Literacy

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 the foundations necessary to develop a functional **scientific literacy**, and assists in building stronger futures for Canada's young people.

The *Pan-Canadian Science Framework* and *Senior 4 Physics: A Foundation for Implementation* are designed to support and promote an attainable and realistic vision for scientific literacy. Student learning outcomes are concise descriptions of the knowledge and skills (and attitudes) that students are expected to learn in a course or grade level in a subject area (Manitoba Education and Training, *A Foundation for Excellence*, 1995).

The Vision of *Senior 4 Physics: A Foundation for Implementation*

The *Pan-Canadian Science Framework* was guided by the vision that all Canadian students, irrespective of gender or cultural background, will have an opportunity to develop their own individual approaches to scientific literacy. Scientific literacy is an ever-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. No less important, scientific literacy should maintain in students a sense of curiosity, wonder, awe, and abiding respect for the world around them.

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, careers, and their future (Council of Ministers of Education, Canada, 1997).

Goals for Canadian Science Education

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

- encourage students at all levels to develop a rational 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 critically address science-related societal, economic, ethical, and environmental issues;
- provide students with a proficiency in science that creates opportunities for them to pursue progressively higher levels of advanced study, preparing them for science-related occupations, and engaging them in science-related activities appropriate to their interests and abilities; and
- develop in students of varying aptitudes and interests a knowledge of the wide variety of careers related to science, technology, and support for the natural and human environments.

Beliefs about Learning, Teaching, and Assessing Science

To promote a rational, achievable approach to developing scientific literacy among future citizens, it is crucial to recognize how students learn, how science can best be taught, and how learning can be assessed. 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, and connections between these realms.

Students learn most effectively—in a Piagetian sense—when their study of science is rooted in concrete learning experiences related to a particular context or situation, and applied to their world of experiences 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 more deeply. Learning involves the process of linking newly constructed understandings *with* prior knowledge, and then adding new contexts and experiences to current understandings. It is increasingly important that physics educators draw professional attention to how fundamental research in learning theory will affect their efforts in the science classroom.

Changing Emphases in Science Education Content Delivery*

The *National Science Education Standards* envision change throughout the system. The science content standards [or student learning outcomes] encompass the following changes in emphases:

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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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
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 a 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

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

- Science Inquiry: Students are encouraged to converse, ask penetrating questions, and then seek to explore their own constructed explanations alongside scientific explanations through guided research, writing, and planned investigations.
- Problem Solving: Students apply their acquired expertise and knowledge in novel, oftentimes unforeseeable, ways.
- Decision Making: As students identify rich, large-context problems, questions, or issues related to the human and robotic exploration of the universe, they pursue new knowledge that will assist them in making informed, rational, defensible decisions that are rooted in the societal and humanistic domains within which science practice operates.
- The Nature of Science: Students appreciate and value the understanding that science operates with the consent of personal, social, political, environmental, and multicultural orientations of the global society. Moreover, there are consequences when science circumvents its responsibilities among these societal contexts.
- Science-Related Skills: Examples of these skills include initiating, planning, performing, recording, analyzing, interpreting, communicating, and team building. All these skills have central importance in learning the dimensions of science. It is important that science students of today not be taught the myth of a single, specifiable "scientific method" that leads to a superior "truth" about the material world. If there is indeed an objective "reality," philosophers of science often agree that it may be difficult to define, or perhaps be unknowable. Nevertheless, the methods of science systematically permit new knowledge domains to be constructed, and that knowledge is often robust and durable.
- Science Content Knowledge: Transmission of science content is no longer considered to be the primary outcome of science teaching. In addition, science knowledge is actively constructed from existing and emerging personal and social knowledge. Creative, integrative, and interdisciplinary linkages should be balanced with the traditional "disciplinary focus" of teaching and learning in physics. Unifying concepts among traditional, bounded, restricted disciplines now give way to, and add form and substance to, new views of exploration among the sciences that are holistic and interdisciplinary.

It is through exposure to these areas that students discover the significance of science in their lives and come to appreciate the interrelatedness of science, technology, society, and the environment. Each 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 a scientific literacy for all, according to personal interests and inclinations, students could become increasingly more engaged in the planning, development, and evaluation of their own learning experiences. They should have the opportunity to work co-operatively with other students, to initiate investigations, to communicate their findings, and to complete projects that demonstrate their learning in a personal, though peer-reviewed, manner. At the beginning of instructional design, teachers and students should identify expected student learning outcomes and establish performance criteria. It is important that these criteria correspond with provincial student learning outcomes. This communication between students and teachers helps to identify clearly what needs to be accomplished, thereby assisting in the learning process (see the rubrics in Appendix 6).

When students are aware of expected outcomes, they will be more focussed on their learning, and may be 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.

NOTES