Senior 3 Current Topics in the Sciences

A Foundation for Implementation

Manitoba
Building for the Future

SENIOR 3 CURRENT TOPICS IN THE SCIENCES

A Foundation for Implementation

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CONTENTS

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.
>
> 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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SECTION 1: MANITOBA FOUNDATIONS FOR SCIENCE LITERACY

MANITOBA FOUNDATIONS FOR SCIENTIFIC LITERACY

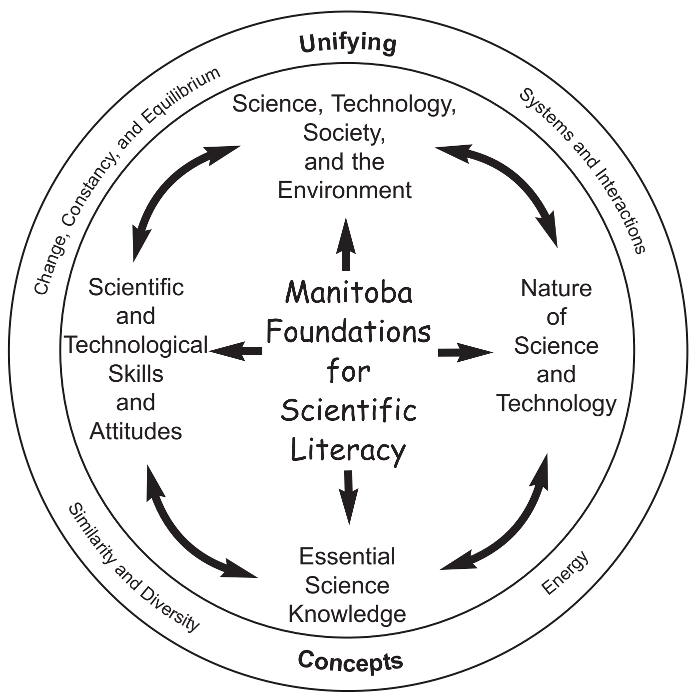
The Five Foundations

To develop scientifically literate students, Manitoba science curricula are built upon five foundations for scientific literacy that have been adapted from the *Pan-Canadian Science Framework* to address the needs of Manitoba students:

- Nature of Science and Technology
- Science, Technology, Society, and the Environment (STSE)
- Scientific and Technological Skills and Attitudes
- Essential Science Knowledge
- Unifying Concepts

The following conceptual organizer illustrates the five foundations for scientific literacy representing the goals of science learning from Kindergarten to Senior 4 in Manitoba.

Manitoba Science Curriculum Conceptual Organizer



These foundations, which are described in more detail on the following pages, have led to the development of four general learning outcomes in Senior 3 Current Topics in the Sciences.

Nature of Science and Technology

Students must learn that science and technology are creative human activities with long histories in all cultures. Science is a way of learning about the universe. This learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over that evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science argue that there is no set procedure for conducting a scientific investigation. Rather, they see science as driven by a combination of theories, knowledge, experiments, and processes anchored in the physical world.

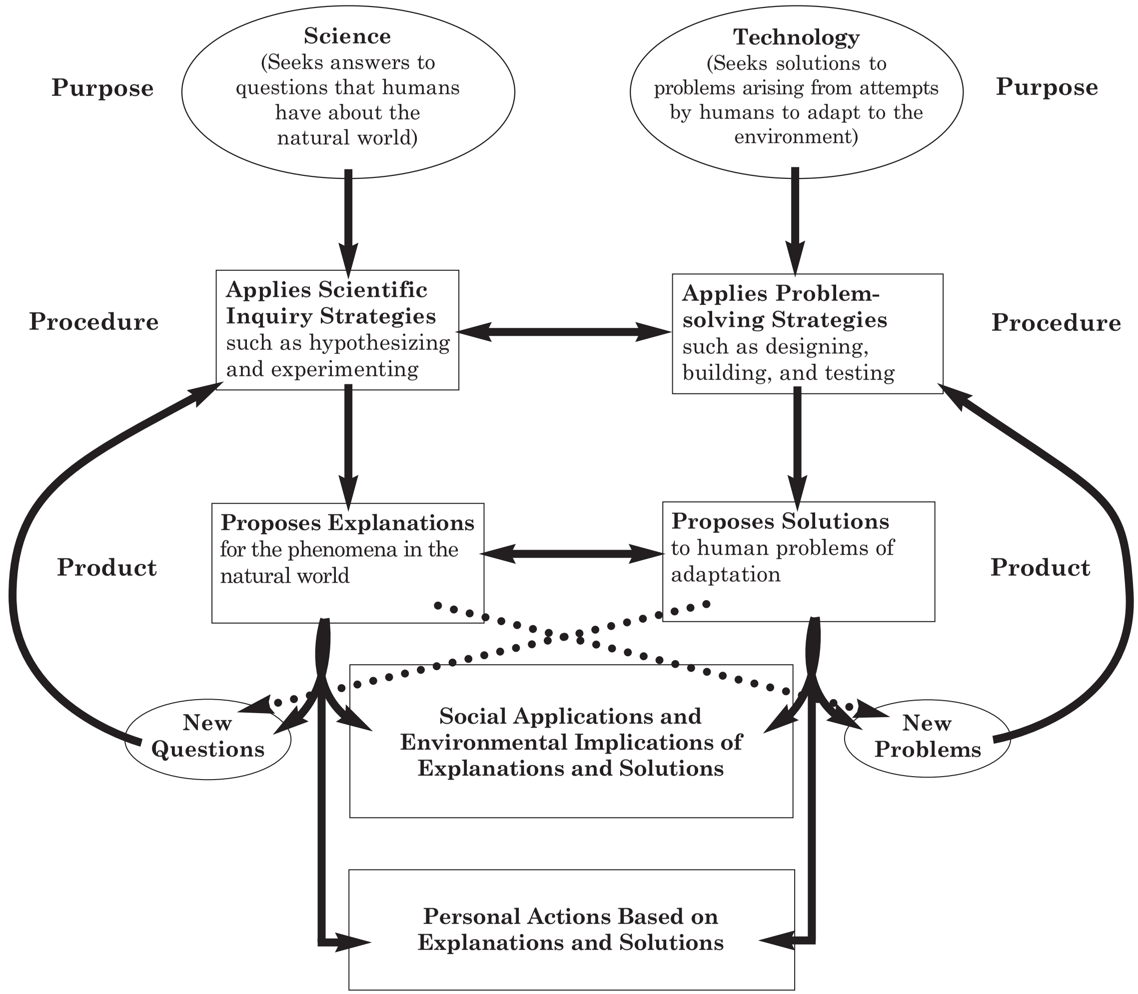
> Producing science knowledge is an intrinsically collective endeavour. There is no such thing as stand-alone science. Scientists submit models and solutions to the assessment of their peers who judge their logical and experimental soundness by reference to the body of existing knowledge (Larochelle and Désautels 235).

Scientific theories are being tested, modified, and refined continually as new knowledge and theories supersede existing ones. Scientific debate on new observations and hypotheses that challenge accepted knowledge involves many participants with diverse backgrounds. This highly complex interplay, which has occurred throughout history, is animated by theoretical discussions; experimentation; social, cultural, economic, and political influences; personal biases; and the need for peer recognition and acceptance. Students will realize that while some of our understandings about how the world works are due to revolutionary scientific developments, many of our understandings result from the steady and gradual accumulation of knowledge.

Technology results mainly from proposing solutions to problems arising from attempts by humans to adapt to the environment. Technology may be regarded as "a tool or machine; a process, system, environment, epistemology, and ethic; the systematic application of knowledge, materials, tools, and skills to extend human capabilities…" (Manitoba Education and Training, *Technology As a Foundation Skill Area* 1). Technology refers to much more than the knowledge and skills related to computers and their applications. Technology is based on the knowledge of concepts and skills from other disciplines (including science) and is the application of this knowledge to meet an identified need or to solve a problem using materials, energy, and tools (including computers). Technology also has an influence on processes and systems, on society, and on the ways people think, perceive, and define their world.

Senior 3 Current Topics in the Sciences emphasizes both the distinctions and relationships between science and technology. The following illustration shows how science and technology differ in purpose, procedure, and product, while at the same time relating to each other.

Science and Technology: Their Nature and Interrelationships



Science and Technology: Their Nature and Interrelationships: Adapted with permission from Rodger W. Bybee, et al., *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction* (Rowley, MA: The NETWORK, Inc., 1989).

Nature of Science and Technology Learning Outcomes

This foundation area has led to the development of the following **general learning outcome** (GLO) in Senior 3 Current Topics in the Sciences:

GLO A: Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

The following **specific learning outcomes** (SLOs) have GLO A as their source:

SLO A1:	Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.
SLO A2:	Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
SLO A3:	Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.
SLO A4:	Recognize that science and technology interact and evolve, often advancing one another.
SLO A5:	Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

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

Understanding STSE is an essential component of scientific literacy. By studying the historical context, students come to appreciate ways in which cultural and intellectual traditions have influenced the questions and methodologies of science, and how science, in turn, has influenced the wider world of ideas.

Today, most scientists work in industry, where projects are more often driven by societal and environmental needs than by pure research. Many technological solutions have evoked complex social and environmental issues. Students, as future citizens, must recognize the potential of scientific literacy to inform and empower decision making of individuals, communities, and society as a whole.

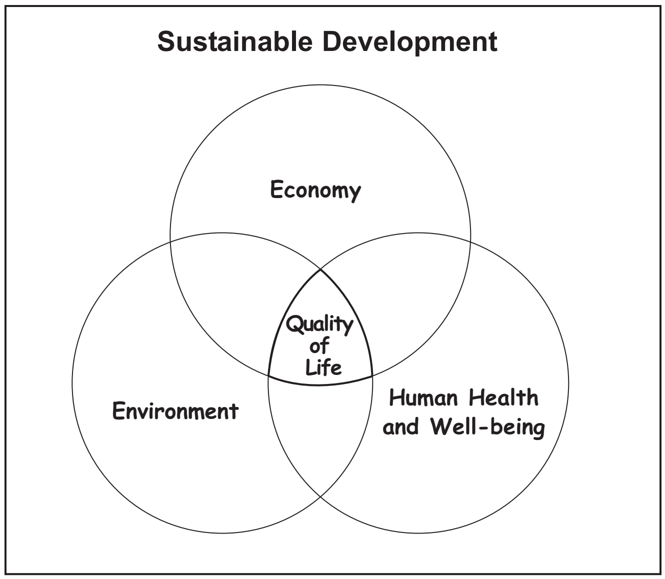
Scientific knowledge is necessary, but not sufficient, for understanding the relationships between science, technology, society, and the environment. To understand these relationships fully, it is essential that students consider the values related to science, technology, society, and the environment.

Sustainable Development As a Decision-Making Model

To achieve scientific literacy, students must also develop an appreciation for the importance of sustainable development. Sustainable development is a decision-making model that considers the needs of both present and future generations, and integrates and balances the **impact of economic activities, the environment**, and the **health and well-being of the community.**

- **Sustainable human health and well-being** is characterized by people coexisting harmoniously within local, national, and global communities and with nature. A sustainable society is one that is physically, psychologically, spiritually, and socially healthy. The well-being of individuals, families, and communities is of considerable importance.

- A **sustainable environment** is one in which the life-sustaining processes and natural resources of the Earth are conserved and regenerated.
- A **sustainable economy** is one that provides equitable access to resources and opportunities. It is characterized by development decisions, policies, and practices that respect cultural realities and differences, and do not exhaust the Earth's resources. A sustainable economy is evident when decisions, policies, and practices are carried out to minimize their impact on the Earth's resources and to maximize the regeneration of the natural environment.
- Decisions or changes related to any one of the three components—human health and well-being, the environment, or the economy—have a significant impact on the other two components and, consequently, on our **quality of life**. Decision making must take into account all three components to ensure an equitable, reasonable, and sustainable quality of life for all.



Educators are encouraged to refer to *Education for a Sustainable Future* (Manitoba Education and Training), a document that outlines ways of incorporating precepts, principles, and practices to foster appropriate learning environments that would help direct students toward a sustainable future.

Sustainable Development, Social Responsibility, and Equity

Sustainable development supports principles of social responsibility and equity. Williams believes that the concept of equity is essential to the attainment of sustainability. This includes equity among nations, within nations, between humans and other species, as well as between present and future generations.

Sustainable development is, at the same time, a decision-making process, a way of thinking, a philosophy, and an ethic. Compromise is an important idea that underlies the decision-making process within a sustainable development approach. In order to achieve the necessary balance between human health and well-being, the environment, and the economy, some compromises will be necessary.

> There can be no greater contribution or more essential element to long-term environmental strategies leading to sustainable development that respects the environment… than the education of future generations in matters relating to the environment (UNESCO).
>
> Public awareness and understanding of the concept of sustainable development and its practices are essential. If we are to change our way of life we must equip present and future generations with the knowledge and training to put sustainable development into effect (Manitoba Sustainable Development Coordination Unit 19).

As students advance from grade to grade, they identify STSE interrelationships and apply decision-making skills in increasingly demanding contexts, such as the following:

- **Complexity of understanding:** from simple, concrete ideas to abstract ideas; from limited knowledge of science to more in-depth and broader knowledge of science and the world
- **Applications in context:** from contexts that are local and personal to those that are societal and global
- **Consideration of variables and perspectives:** from one or two that are simple to many that are complex
- **Critical judgement:** from simple right or wrong assessments to complex evaluations
- **Decision making:** from decisions based on limited knowledge, made with the teacher's guidance, to decisions based on extensive research, made independently using personal judgement

Science, Technology, Society, and the Environment Learning Outcomes

This foundation area has led to the development of the following **general learning outcome** (GLO) in Senior 3 Current Topics in the Sciences:

GLO B: Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

The following **specific learning outcomes** (SLOs) have GLO B as their source:

SLO B1:	Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.
SLO B2:	Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.
SLO B3:	Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.
SLO B4:	Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.
SLO B5:	Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

Scientific and Technological Skills and Attitudes

A science education that strives for scientific literacy must engage students in answering questions, solving problems, and making decisions. These processes are referred to as scientific inquiry, technological problem solving (design process), and decision making (see chart below). While the skills and attitudes involved in these processes are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

Processes for Science Education

	Scientific Inquiry	**Technological Problem Solving (Design Process)**	**Decision Making**
Purpose:	Satisfying curiosity about events and phenomena in the natural world.	Coping with everyday life, practices, and human needs.	Identifying different views or perspectives based on varying information.
Procedure:	What do we know? What do we want to know?	How can we do it? Will it work?	What are the alternatives or consequences? Which choice is best at this time?
Product:	Knowledge about events and phenomena in the natural world.	An effective and efficient way to accomplish a task or meet a need.	A defensible decision in a particular circumstance.

	Scientific Question	**Technological Problem**	**STSE Issue**
Example:	Why does my coffee cool so quickly? *An Answer:* Heat energy is transferred by conduction, convection, and radiation to the surrounding environment.	How can I keep my coffee hot? *A Solution:* A plastic foam cup will keep liquids warm for a long time. So will an insulated cup.	Should we use plastic foam cups or ceramic mugs for our meeting? *A Decision:* Since we must use disposable cups for the meeting, we will choose a biodegradable type.

Processes for Science Education: Adapted with permission of the Minister of Education, Province of Alberta, Canada, 2005.

A description of each of these **processes** follows. **Attitudes**, an important element of each process, are also examined.

Scientific Inquiry

Scientific inquiry is a way of learning about the universe. It involves posing questions and searching for explanations of phenomena. Although no single "scientific method" exists, students require certain skills to participate in science-related experiences.

Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, and collecting, analyzing, and interpreting data are fundamental to scientific inquiry—as are attitudes such as curiosity, skepticism, and creativity. These skills are often represented as a cycle. This cycle involves posing questions, generating possible explanations, and collecting and analyzing evidence to determine which of these explanations is most useful and accurate in accounting for the phenomena under investigation. New questions may arise to reignite the cycle. It must be noted, however, that many scientific inquiries (past and present) do not necessarily follow a set sequence of steps, nor do they always start at the "beginning" of the cycle; scientists can be creative and responsive to scientific challenges as they arise.

Technological Problem Solving

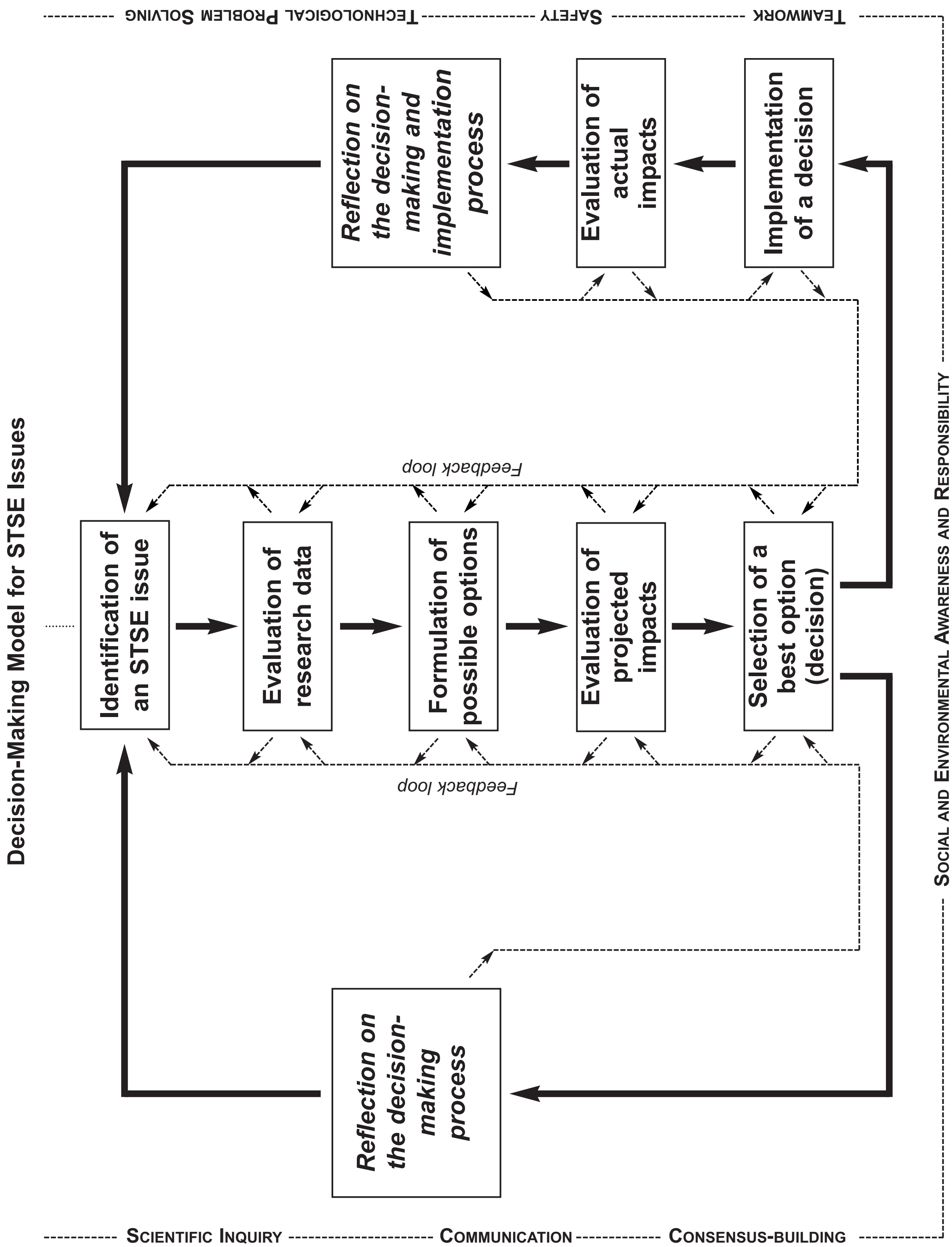
Technological problem solving seeks solutions to problems arising from attempts by humans to adapt to or change the environment. In Kindergarten to Grade 8 science, students have been developing these skills using a cycle of steps called the **design process**. This design process includes the proposing, creating, and testing of prototypes, products, and techniques in an attempt to reach an optimal solution to a given problem. Feedback and evaluation are built into this cycle. In Senior Years science, these technological problem-solving skills are incorporated into a decision-making process.

STSE Issues and Decision Making

Students, as individuals and global citizens, are required to make decisions. Increasingly, the types of issues they face demand an ability to apply scientific and technological knowledge, processes, and products to the decisions they make related to Science, Technology, Society, and the Environment (STSE). The decision-making process involves a series of steps, which may include

- clarifying the issue
- critically evaluating all available research
- generating possible courses of action
- making a thoughtful decision
- examining the impact of the decision
- reflecting on the process

Students should be actively involved in decision-making situations as they progress through their science education. Not only are decision-making situations important in their own right, but they also provide a relevant context for engaging in scientific inquiry, problem solving, and the study of STSE relationships, as shown in the following illustration.



Decision-Making Model for STSE Issues: Reproduced from Manitoba Education and Youth, *Senior 2 Science: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Youth, 1999) Introduction–12.

Attitudes

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

Scientific and Technological Skills and Attitudes Learning Outcomes

This foundation area has led to the development of the following **general learning outcome** (GLO) in Senior 3 Current Topics in the Sciences:

GLO C: Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.

The following **specific learning outcomes** (SLOs) have GLO C as their source:

SLO C1:	Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
SLO C2:	Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.
SLO C3:	Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.
SLO C4:	Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.
SLO C5:	Work cooperatively with others and value their ideas and contributions.

Essential Science Knowledge

The subject matter of science includes theories, models, concepts, and principles that are essential to an understanding of life science, physical science, and Earth and space science. Content is a vehicle for essential learnings (Drake).

- **Life science** deals with the growth and interactions of life forms within their environment in ways that reflect their uniqueness, diversity, genetic continuity, and changing nature. Life science includes the study of organisms (including humans and cells), ecosystems, biodiversity, biochemistry, and biotechnology, to name a few.
- **Physical science**, which encompasses chemistry and physics, deals with matter, energy, and forces. Matter has structure, and interactions exist among its components. Energy links matter to gravitational, electromagnetic, and nuclear forces of the universe. The laws of conservation of mass and energy, momentum, and charge are addressed by physical science.
- **Earth and space science** brings local, global, and universal perspectives to students' knowledge. The Earth exhibits form, structure, and patterns of change, as does our surrounding solar system and the physical universe beyond. Earth and space science includes fields of study such as geology, hydrology, meteorology, and astronomy.

Unifying Concepts

An effective way to create linkages within and among science disciplines is to use unifying concepts—the key ideas that underlie and integrate all science knowledge and extend into areas such as mathematics and social studies. Unifying concepts help students construct a holistic understanding of science and its role in society.

Essential Concepts Learning Outcomes

The two previous foundation areas, Essential Science Knowledge and Unifying Concepts, have led to the development of the following **general learning outcome** (GLO) in Senior 3 Current Topics in the Sciences:

GLO D: Explore, understand, and use scientific knowledge in a variety of contexts.

The following **specific learning outcomes** (SLOs) have GLO D as their source:

SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.
SLO D2:	Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.
SLO D3:	Understand the processes and conditions in which change, constancy, and equilibrium occur.
SLO D4:	Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

Senior 3 Current Topics in the Sciences

By offering a multidisciplinary focus, Senior 3 Current Topics in the Sciences provides a solid foundation for scientific literacy. The curriculum, consisting of four general learning outcomes (GLOs), each with a number of specific learning outcomes (SLOs), will build upon what Senior 3 students know and are able to do as a result of their studies in Kindergarten to Senior 2 science.

The following chart identifies thematic clusters from Kindergarten to Senior 2 Science. It allows teachers to examine at a glance students' previous exposure to scientific knowledge in different areas.

Topic Chart for Kindergarten to Senior 2 Science

Clusters / Grades	Cluster 0	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Kindergarten	**Overall Skills and Attitudes** (To Be Integrated into Clusters 1 to 4)	Trees	Colours	Paper	—-
Grade 1		Characteristics and Needs of Living Things	The Senses	Characteristics of Objects and Materials	Daily and Seasonal Changes
Grade 2		Growth and Changes in Animals	Properties of Solids, Liquids, and Gases	Position and Motion	Air and Water in the Environment
Grade 3		Growth and Changes in Plants	Materials and Structures	Forces That Attract or Repel	Soils in the Environment
Grade 4		Habitats and Communities	Light	Sound	Rocks, Minerals, and Erosion
Grade 5		Maintaining a Healthy Body	Properties of and Changes in Substances	Forces and Simple Machines	Weather
Grade 6		Diversity of Living Things	Flight	Electricity	Exploring the Solar System
Grade 7		Interactions within Ecosystems	Particle Theory of Matter	Forces and Structures	Earth's Crust
Grade 8		Cells and Systems	Optics	Fluids	Water Systems
Senior 1		Reproduction	Atoms and Elements	Nature of Electricity	Exploring the Universe
Senior 2		Dynamics of Ecosystems	Chemistry in Action	In Motion	Weather Dynamics

SECTION 2: IMPLEMENTATION OF SENIOR 3 CURRENT TOPICS IN THE SCIENCES

IMPLEMENTATION OF SENIOR 3 CURRENT TOPICS IN THE SCIENCES

The Senior 3 Student and the Science Learning Environment

An understanding of the unique qualities of each student and how each one learns will aid in making decisions regarding curricular content, learning materials and resources, and instructional and assessment strategies.

In recent decades, cognitive psychology, brain-imaging technology, and multiple intelligences theory have transformed our understanding of learning. Ongoing professional development is important to teachers as they seek to update their knowledge of the processes of learning.

The students that teachers encounter today are different in many respects from students a generation ago. Students are more likely to be living with a single parent or stepfamily. More have part-time jobs. Students are more sophisticated in their knowledge and use of information technology, and much of their understanding of the world comes from television. Classrooms are more likely to be ethnically diverse.

Family relationships, academic and life experiences, personality, interests, learning approaches, socioeconomic status, and rate of development all influence a student's ability to learn.

Characteristics of Senior 3 Learners

For many students, Senior 3 is a stable and productive year. Many Senior 3 students have developed a degree of security within their peer group and a sense of belonging in school. They show increasing maturity in dealing with the freedoms and responsibilities of late adolescence: romantic relationships, part-time jobs, and driver's licences. In Senior 3, most students have a great deal of energy and a growing capacity for abstract and critical thinking. Many are prepared to express themselves with confidence and to take creative and intellectual risks. The stresses and preoccupations of preparing for graduation, post-secondary education, or full-time jobs are still a year away. For many students, Senior 3 may be their most profitable academic year of the Senior Years.

Although many Senior 3 students handle their new responsibilities and the demands on their time with ease, others experience difficulty. External interests may seem more important than school. Because of their increased autonomy, students who previously had problems managing their behaviour at school may now express their difficulties through poor attendance, alcohol and drug use, or other behaviours that place them at risk.

Students struggling to control their lives and circumstances may make choices that seem contrary to their best interests. Communication with the home and awareness of what students are experiencing outside school continue to be important for Senior 3 teachers. Although the developmental variance evident in previous years has narrowed, students in Senior 3 can still change a great deal in the course of one year or even one semester.

Characteristics of Senior 3 Learners: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 1-4 to 1-5.

Sensitivity to the dynamic classroom atmosphere and recognition when shifts in interests, capabilities, and needs are occurring allows teachers to adjust learning experiences for their students.

The following chart identifies some common characteristics of late adolescence observed in educational studies (Glatthorn; Maxwell and Meiser; Probst) and by Manitoba teachers, and discusses the implications of these characteristics for teachers.

Senior 3 Learners: Implications for Teachers

Characteristics of Senior 3 Learners	Significance for Senior 3 Teachers
Cognitive Characteristics	
• Most Senior 3 learners are capable of abstract thought and are in the process of revising their former concrete thinking into fuller understanding of principles.	• Teach to the big picture. Help students forge links between what they already know and what they are learning. Be cognizant of individual differences and build bridges for students who think concretely.
• Students are less absolute in their reasoning, more able to consider diverse points of view. They recognize that knowledge may be relative to context.	• Focus on developing problem-solving and critical-thinking skills, particularly those related to STSE and decision making.
• Many basic learning processes have become automatic by Senior 3, freeing students to concentrate on complex learning.	• Identify the knowledge, skills, and strategies that students already possess, and build the course around new challenges. Through assessment, identify students who have not mastered learning processes at Senior 3 levels and provide additional assistance and support.
• Students have a clearer self-understanding and have developed specialized interests and expertise. They need to connect what they are learning to the world outside the school.	• Use strategies that enhance students' metacognition. Encourage students to develop scientific skills through exploring areas of interest. Cultivate classroom experts and invite students with individual interests to enrich the learning experience of the class.
Psychological and Emotional Characteristics	
• It is important for Senior 3 students to see that their autonomy and emerging independence are respected. They need a measure of control over what happens to them in school.	• Provide choice. Allow students to select many of the resources they will explore and the forms they will use to demonstrate their learning. Collaborate with students in assessment. Teach students to be independent learners. Gradually release responsibility to students.
• Students are preparing for senior leadership roles within the school and may be more involved with leadership in their communities.	• Provide students with leadership opportunities within the classroom and with a forum to practise skills in public speaking and group facilitation.
• Students need to understand the purpose and relevance of practices, policies, and processes. They may express their growing independence through a general cynicism about authority and institutions.	• Use students' tendency to question social mores to help them develop critical thinking. Negotiate policies and demonstrate a willingness to make compromises. Use students' questions to fuel classroom inquiry.
• Senior 3 students have a clearer sense of identity than they had previously and are capable of being more reflective and self-aware. Some students are more willing to express themselves and disclose their thoughts and ideas.	• Provide optional and gradual opportunities for self-disclosure. Invite students to explore and express themselves through their work. Celebrate student differences.

(continued)

Senior 3 Learners: Implications for Teachers: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 1-5 to 1-7.

Senior 3 Learners: Implications for Teachers *(continued)*	
Characteristics of Senior 3 Learners	**Significance for Senior 3 Teachers**
Physical Characteristics	
• Many Senior 3 students have reached adult physical stature. Others, particularly males, are still in a stage of extremely rapid growth and experience a changing body image and self-consciousness.	• Be sensitive to the risk students may feel in public performances and increase expectations gradually. Provide students with positive information about themselves.
• By Senior 3, students are able to sit still and concentrate on one learning task for longer periods than previously, but they still need interaction and variety. They have a great deal of energy.	• Put physical energy to the service of active learning instead of trying to contain it. Provide variety; change the pace frequently; use kinesthetic learning experiences.
• Senior 3 students still need more sleep than adults do, and may come to school tired as a result of part-time jobs or activity overload.	• Be aware that inertia or indifference may be the result of fatigue. Work with students and families to set goals and plan activities realistically so that school work assumes a higher priority.
Moral and Ethical Characteristics	
• Senior 3 students are working at developing a personal ethic, rather than following an ascribed set of values and code of behaviour.	• Explore the ethical meaning of situations in life and in scientific contexts. Provide opportunities for students to reflect on their thoughts in discussion, writing, or representation.
• Students are sensitive to personal or systemic injustice but are increasingly realistic about the factors affecting social change.	• Explore ways decision-making activities can effect social change and link to the continuum of science, technology, society, and the environment.
• Students are shifting from an egocentric view of the world to one centred in relationships and community. They are able to recognize different points of view and adapt to difficult situations.	• Provide opportunities for students to make and follow through on commitments and to refine their interactive skills.
• Students are becoming realistic about the complexities of adult responsibilities but resist arbitrary authority.	• Explain the purpose of every learning experience. Enlist student collaboration in developing classroom policies. Strive to be consistent.
Social Characteristics	
• By Senior 3, certain individuals will take risks in individual identity. Many students, however, continue to be intensely concerned with how peers view their appearance and behaviour. Much of their sense of self is drawn from peers, with whom they may adopt a "group consciousness," rather than from making autonomous decisions.	• Ensure that the classroom has an accepting climate. Model respect for each student. Use learning experiences that foster student self-understanding and self-reflection. Challenge students to make personal judgements about situations in life and in their natural environment.
• Adolescents frequently express identification with peer groups through slang, musical choices, clothing, body decoration, and behaviour.	• Foster a classroom identity and culture. Ensure that every student is included and valued. Structure learning so that students can interact with peers, and teach strategies for effective interaction.
• Crises of friendship and romance and a preoccupation with relationships can distract students from academics.	• Open doors for students to study relationships in science (for example, through biographies of scientists). Respect confidentiality, except where a student's safety is at risk.
• Students begin to recognize teachers as individuals and welcome a personal connection.	• Nurture and enjoy a relationship with each student. Try to find areas of common interest with each one. Respond with openness, empathy, and warmth.

Fostering a Will to Learn

Experiences of intense involvement are optimal opportunities for teaching engagement in learning, and teachers should endeavour to ensure they happen frequently in the classroom. Not every necessary learning task, however, can be intrinsically rewarding to every learner. Being a successful learner also requires a high degree of what Corno and Randi call "sustained voluntary effort"—an attitude that is expressed in committing oneself to less interesting tasks, persisting in solving problems, paying conscientious attention to detail, managing time, self-monitoring, and making choices between competing values, such as the desire to do well on a homework assignment and the desire to spend the evening with friends. The willingness to make this sustained effort constitutes motivation.

Motivation is a concern of teachers, not only because it is essential to classroom learning, but also because volition and self-direction are central to lifelong learning. Science courses seek to teach students how to interpret and analyze science concepts, and to foster the desire to do so. Motivation is not a single factor that students either bring or do not bring to the classroom. It is multi-dimensional, individual, and often comprises both intrinsic and extrinsic elements. Students hold certain presuppositions about science learning that affect the way they learn. There are certain attitudes and skills that teachers can promote to facilitate students' engagement in each learning task, while recognizing and affirming entry-level abilities.

In considering how they can foster motivation, teachers may explore students' appreciation of the value (intrinsic and extrinsic) of learning experiences and their belief about their likelihood of success. Good and Brophy suggest that these two elements can be expressed as an equation: the effort students are willing to expend on a task is a product of their expectation of success and of the value they ascribe to success.

Expectancy	**x**	**Value**	**=**	**Motivation**
(the degree to which students expect to be able to perform the task successfully if they apply themselves)		(the degree to which students value the rewards of performing the task successfully)		

Teachers may, therefore, want to focus on ensuring students can succeed if they apply reasonable effort, and on helping students recognize the value of classroom learning experiences. The following chart provides teachers with suggestions for fostering motivation.

Fostering a Will to Learn: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 1-8.

Fostering Motivation	
Ways to Foster Expectations of Success	**Best Practice and Research**
• Help students to develop a sense of self-efficacy, a confidence in their leaning capabilities.	• Schunk and Zimmerman found that students who have a sense of self-efficacy are more willing to participate, work harder, persist longer when they encounter difficulties, and achieve at a higher level than students who doubt their learning capabilities. • Teachers foster student self-efficacy by recognizing that each student can succeed and by communicating that belief to the student. Silver and Marshall found that a student's perception that he or she is a poor learner is a strong predictor of poor performance, overriding natural ability and previous learning. All students benefit from knowing that the teacher believes they can succeed and will provide the necessary supports to ensure that learning takes place. • Teachers also foster a sense of self-efficacy by teaching students that they can learn how to learn. Students who experience difficulty often view the learning process as mysterious and outside their control. They believe that others who succeed in school do so entirely because of natural, superior abilities. It is highly motivating for these students to discover that they, too, can learn and apply the strategies that successful students use when learning.
• Help students to learn about and monitor their own learning processes.	• Research shows that students with high metacognition (students who understand how they learn) learn more efficiently, are more adept at transferring what they know to other situations, and are more autonomous than students who have little awareness of how they learn. Teachers enhance metacognition by embedding, into all aspects of the curriculum, instruction in the importance of planning, monitoring, and self-assessing. Turner found that teachers foster a will to learn when they support "the cognitive curriculum with a metacognitive and motivational one" (199).
• Assign tasks of appropriate difficulty, communicating assessment criteria clearly, and ensuring that students have clear instruction, modelling, and practice so they can complete the tasks successfully.	• Ellis et al found that systematic instruction helps students learn strategies they can apply independently.
• Help students to set specific and realistic personal goals and to learn from situations where they do not attain their goals. Celebrate student achievements.	• Research shows that learning is enhanced when students set goals that incorporate specific criteria and performance standards (Foster; Locke and Latham). • Teachers promote goal-setting skills by working in collaboration with students in developing assessment strategies and rubrics (see Section 3 and Appendix 8).

(continued)

Fostering Motivation: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 1-9 to 1-10.

Fostering Motivation *(continued)*	
Ways to Foster Expectations of Success	**Best Practice and Research**
• Offer choices.	• Intrinsic motivation is closely tied to students' self-selection of topics, texts, learning activities, and creative forms. Teachers may involve students in the choice of a topic for thematic development. Teachers need to support students in the search for learning resources that are developmentally appropriate and of high interest, and encourage students to bring the world views they value into the classroom. Self-selection allows students to build their learning on the foundation of their personal interests and enthusiasm.
• Set worthwhile academic objectives.	• Rather than asking students to execute isolated skills or perform exercises that are without context, teachers need to embed instruction in meaningful events and activities that simulate real-world settings, and ensure that students share performances and products with a peer audience.
• Help students to learn about and monitor their own learning processes.	• In teaching specific learning strategies, teachers need to focus on the usefulness of each strategy for making meaning of information or for expressing ideas of importance to students. Teachers need to emphasize the importance of science to the richness and effectiveness of students' lives, and de-emphasize external rewards and consequences such as marks.
• Ensure that scientific experiences are interactive.	• A community that encourages students to share their learning with each other values science. Teachers who model curiosity, enthusiasm, and pleasure in learning science-related concepts and who share their experiences foster motivation for scientific literacy.

Creating a Stimulating Learning Environment

A vital science class grows out of, and is reflected in, a stimulating and inviting physical environment. While the resources and physical realities of classrooms vary, a well-equipped science classroom offers or contains a variety of resources that help stimulate learning. It is helpful to involve students in the classroom design.

Ways to create a stimulating learning environment include the following:

- **Flexible seating arrangements:** Use movable desks or tables to design seating arrangements that reflect a student-centred philosophy and that allow students to interact in various configurations.
- **A media-rich environment:** Have a classroom library of books for self-selected reading. The classroom library may include science periodicals, newspaper articles, newsletters, Internet articles, science-fiction literature, and students' published work. It may also include a binder of student reviews and recommendations, and may be decorated by student-designed posters or book jackets. Classroom reference materials could include dictionaries/encyclopedias of science, books of facts, software and CD-ROM titles, past examinations collated into binders, and manuals.
- **Access to electronic equipment:** Provide access to a computer, television, video cassette recorder, and videorecorder, if possible.
- **Wall displays:** Exhibit posters, Hall of Fame displays, murals, banners, and collages that celebrate student accomplishments. Change these frequently to reflect student interests and active involvement in the science classroom.
- **Display items and artifacts:** Have models, plants, photographs, art reproductions, newspaper and magazine clippings, fossils, musical instruments, and so on, in your classroom to stimulate inquiry and to express the link between the science classroom and the larger world.
- **Animals:** Provide interaction with an assortment of classroom animals.
- **Communication:** Post checklists, processes, and strategies to facilitate and encourage students' independent learning. Provide a bulletin board for administrative announcements and schedules.
- **Well-equipped and safe laboratory:** Provide regular access to a well-equipped and safe science lab to foster the development of critical lab skills.

Language Learning Connected to Science

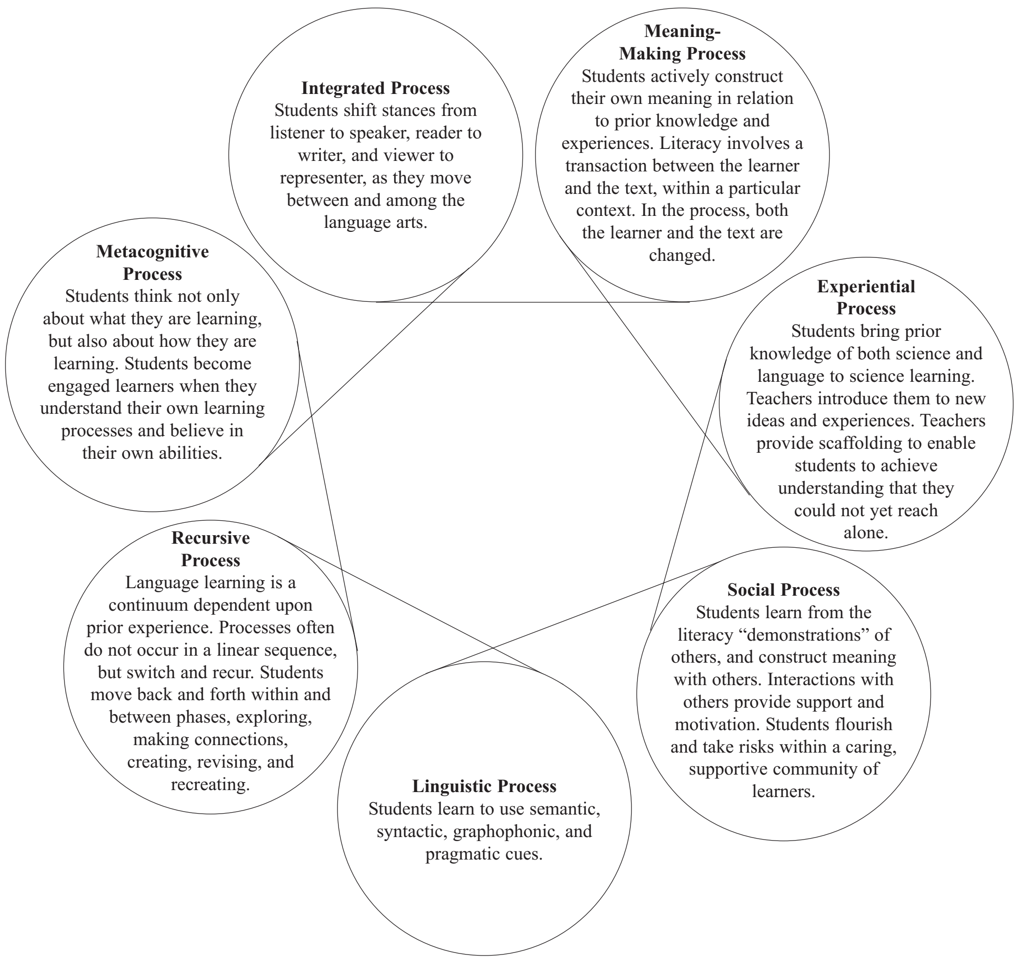
Science curricula involve all aspects of language and literacy development. Halliday (cited in Strickland and Strickland 203) suggests that as students actively use the language arts, they engage in three kinds of language learning, which can be linked to broader scientific literacy:

- **Students learn language:** Language learning is a social process that begins at infancy and continues throughout life. Language-rich environments enhance and accelerate the process. Terminology-rich science has a role in new language development.
- **Students learn through language:** As students listen, read, or view, they focus primarily on making meaning from the text at hand. Students use language to increase their knowledge of the world.

- **Students learn about language:** Knowledge of language and how it works is a subject in and of itself; nevertheless, science as a discipline of inquiry relies on a particular use of language for effective communication. Consequently, students also focus on the language arts and their role when applied to science.

Scientific literacy learning is dynamic and involves many processes. The following graphic identifies some of the dynamic processes that form the foundation for effective literacy learning in science classrooms.

Dynamic Processes in Literacy Learning Integrated into Science



Dynamic Processes in Literacy Learning Integrated into Science: Adapted from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998) Overview–11.

The Nature of Science, Scientific Theories, and Science Education Today

Science is a method of explaining the natural world. It assumes that anything that can be observed or measured is amenable to scientific investigation. Science also assumes that the universe operates according to regularities that can be discovered and understood through scientific investigations. The testing of various explanations of natural phenomena for their consistency with empirical data is an essential part of the methodology of science. Explanations that are not consistent with empirical evidence or cannot be tested empirically are not a part of science. As a result, explanations of natural phenomena that are not based on evidence but on myths, personal beliefs, religious values, and superstitions are not scientific. Furthermore, because science is limited to explaining natural phenomena through the use of empirical evidence, it cannot provide religious or ultimate explanations.

The most important scientific explanations are usually termed "theories." In ordinary speech, "theory" is often used to mean "guess" or "hunch," whereas in scientific terminology, a theory is a set of universal statements that explain some aspect of the natural world. Theories are powerful tools. Scientists seek to develop theories that

- are firmly based upon evidence
- are logically consistent with other well-established principles
- explain more than rival theories
- have the potential to lead to new knowledge

The body of scientific knowledge changes as new observations and discoveries are made. Theories and other explanations change. New theories emerge, and other theories are modified or discarded. Throughout this process, theories are formulated and tested on the basis of evidence, internal consistency, and their explanatory power.

Ethical Issues and the Nature of Scientific Theories

The development of thematic units in Senior 3 Current Topics in the Sciences should lead to issues and questions that go beyond a traditional acquisition of scientific knowledge. For example, the application of population biology research to the reintroduction of species into former habitats, or the implementation of international protocols related to global climate change, raises questions of ethics, values, and responsible use of scientific information. The environmental consequences of the industrial applications of chemistry, or climate change science, raise issues of considerable merit, as do the topics of cloning and genetically modified foods. These are among the important issues that science is often called upon for advice. As students and teachers address these issues, they will naturally be drawn to the study of the underlying scientific concepts. Students should realize that science provides the background for informed personal and social decisions and that, as informed decision-makers, they may have an impact on society and the world.

Although the specific learning outcomes of Senior 3 Current Topics in the Sciences do not specifically ask students to engage in ethical considerations (to be emphasized in Senior 4), teachers are encouraged to give ethics and values appropriate treatment, particularily if a unit has an emphasis on the Nature of Science and Technology (GLO A) or on Science, Technology, Society, and the Environment (GLO B).

Instructional Philosophy in Science

Teaching Senior 3 Current Topics in the Sciences through a focus on current issues naturally allows for the use of a variety of instructional strategies that include the collection and analysis of data from both laboratory and field work; group and individual instruction; a diversity of questioning techniques; decision-making, problem-solving, and design-process activities; and a resource-based approach to learning. Senior Years science programming fosters critical thinking skills and promotes the integration of knowledge and application of facts to real-life situations. Scientific concepts from other Senior Years science courses may become part of the subject matter as units develop in Senior 3 Current Topics in the Sciences. This approach is a valuable and useful means of reinforcing and validating interdisciplinary concepts as having relevant and contextual applications.

In general, science is a way of thinking that has rules for judging the validity of answers applicable to everyday life. Science is an intense human activity, full of trial and error, that is influenced by cultural priorities and perspectives. The myth of total objectivity that often permeates scientific dialogue also needs to be exposed. Among the natural sciences, truth is no longer viewed as an objective reality awaiting discovery; rather, it is placed in the context of something always to be sought. In recognition of the tentative nature of current knowledge claims, “scientific truth” is not a goal that can be reached in absolute terms.

Students should be encouraged to make distinctions between what is observable and testable, as well as develop the ability to consider the abstract deductions, models, and themes that flow from evolving scientific research and thinking.

Conceptual knowledge in science must also be integrated with principles from other disciplines. The inclusion of social, historical, and political implications in the study of science provides students with opportunities to develop a facility to communicate ideas effectively through verbal and written expression. Finally, students will benefit from opportunities to develop an awareness of the options available to them for careers and vocations in the wide diversity of sciences.

Senior 3 Current Topics in the Sciences, as a component of young people’s whole educational experience, will help prepare them for a full and satisfying life in the world of the 21st century. This curriculum will sustain and develop the curiosity of young people about the natural world around them, and build their confidence in their ability to inquire into its behaviour, now and in the future. It seeks to foster a sense of wonder, enthusiasm, and interest in science so that young people feel confident and competent to engage with everyday scientific and technological applications and solutions. As students study a range of topics through various themes, they will acquire a broad, general understanding of the important ideas and explanatory frameworks of science, and of the procedures of scientific inquiry, which have had a major impact on our material environment and on our culture. They will develop an appreciation for why these ideas are valued and the underlying rationale for decisions that they may wish, or be advised, to take in everyday contexts, both now and in later life. They will be able to understand, and respond critically to, media reports of issues with a science component. They will feel empowered to hold and express a personal point of view on issues with a science component that enter the arena of public debate, and perhaps to become actively involved in some of these issues (Alsop and Benoze; Millar and Osborne 12).

Results-Based Learning

In results-based learning, the programming focus is on what students know and can do, rather than on what material is "covered." The learning outcomes are an elaboration of the knowledge, skills and strategies, and attitudes expected of each Senior 3 Current Topics in the Sciences student. All programming decisions are directed toward addressing the gap between students' present level of performance and the performance specified in the learning outcomes.

Bridging the Gap Between
Student Performance and the Identified Learning Outcomes

Present Level of Student Performance → Programming Decisions → Senior 3 Student Learning Outcomes

- Instructional Strategies
- Materials and Resources
- Assessment Tools and Strategies

The student learning outcomes are not taught separately or in isolation. Nor are they taught consecutively in the order in which they appear in the curriculum documents. Most lessons or units draw on knowledge, skills and strategies, and attitudes addressed in several or all general learning outcomes. In the process of planning, teachers are encouraged to identify the learning outcomes they intend to assess.

In implementing results-based curricula, teachers may find that they use many of the instructional strategies and resources they have used previously. However, the nature of results-based learning will reshape their programming in several ways:

- Planning is ongoing throughout the semester or year because instruction is informed by learning requirements that become evident through continuous assessment.
- Many learning outcomes are addressed repeatedly in different ways throughout the school semester or year. The learning outcomes should be mastered by the end of the semester/year. As well as developing new scientific knowledge, skills and strategies, and attitudes, students need to practise and refine those learned previously.

Varied Instructional Approaches

Teachers wear a number of different "pedagogical hats," and change their teaching styles in relation to the cognitive gains, attitudes, and skills demanded of the task at hand (Hodson). In planning instruction for Senior 3 Current Topics in the Sciences, teachers may draw upon a repertoire of instructional approaches and methods and use combinations of these in each unit and lesson.

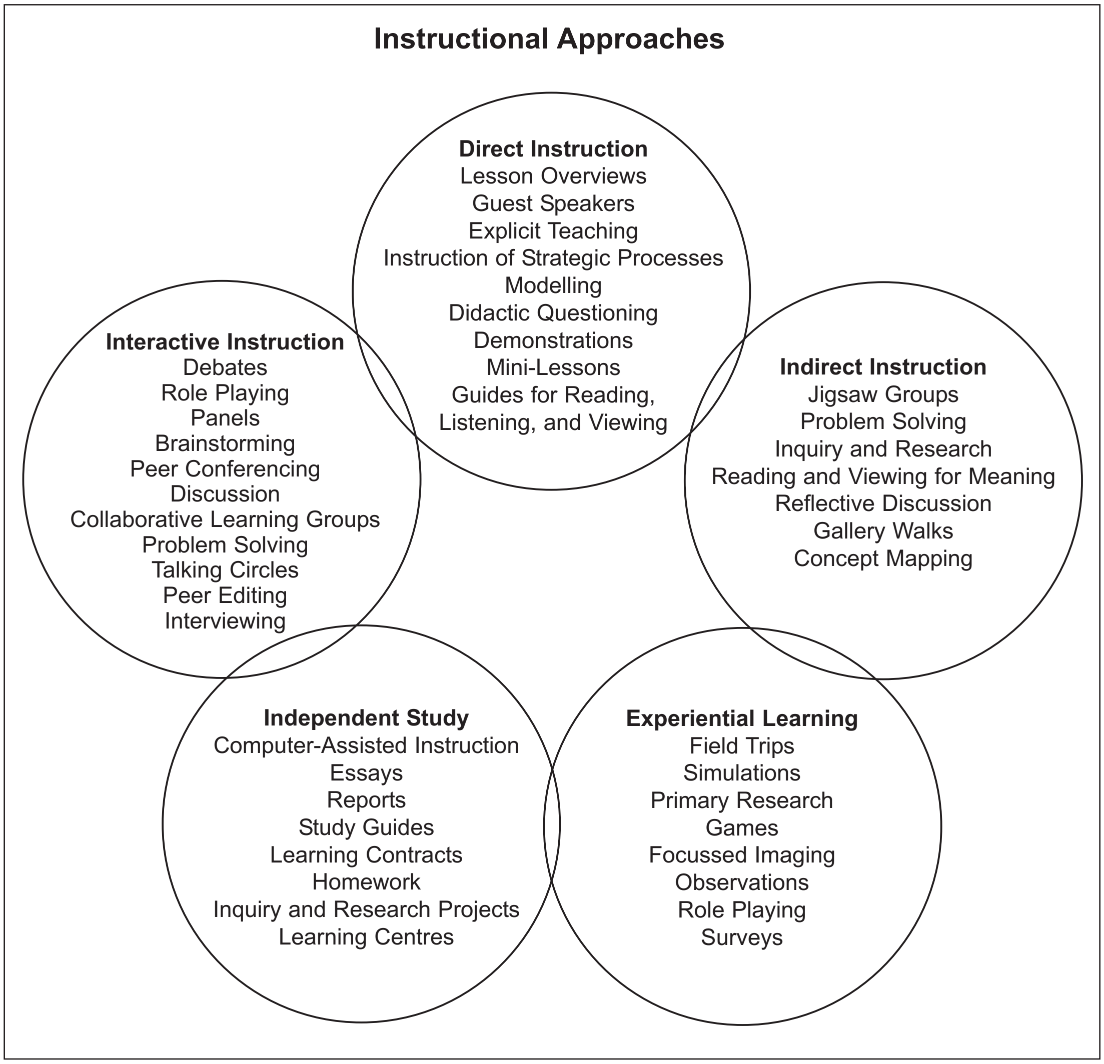
Instructional approaches may be categorized as

- direct instruction
- indirect instruction
- experiential learning
- independent study
- interactive instruction

Results-Based Learning and Varied Instructional Approaches: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 2-3.

Most teachers draw from all these categories to ensure variety in their classroom learning experiences, to engage students with various intelligences and a range of learning approaches, and to achieve instructional goals.

The following diagram displays instructional approaches and suggests some examples of methods within each approach. Note that the approaches overlap.



In selecting instructional approaches and methods, teachers consider which combination will assist students in achieving the learning outcomes targeted for a particular lesson or unit. Teachers consider the advantages and limitations of the approaches and methods, as well as the interests, knowledge, skills, and attitudes of their students. Some of these elements are represented in the following chart.

Instructional Approaches: Adapted from Saskatchewan Education, *Instructional Approaches: A Framework for Professional Practice* (Regina, SK: Saskatchewan Education, 1991) 20. Adapted by permission of Saskatchewan Learning.

Instructional Approaches: Roles, Purposes, and Methods				
Instructional Approaches	**Roles**	**Purposes/Uses**	**Methods**	**Advantages/ Limitations**
Direct Instruction	• Highly teacher-directed • Teacher uses didactic questioning to elicit student involvement	• Providing information • Developing step-by-step skills and strategies • Introducing other approaches and methods • Teaching active listening and note making	Teachers: • Explicit teaching • Lesson overviews • Guest speakers • Instruction of strategic processes • Lecturing • Didactic questioning • Demonstrating and modelling prior to guided practice • Mini-lessons • Guides for reading, listening, and viewing	• Effective in providing students with knowledge of steps of highly sequenced skills and strategies • Limited use in developing abilities, processes, and attitudes for critical thinking and interpersonal learning • May encourage passive not active learning
Indirect Instruction	• Mainly student-centred • Teacher's role shifts to facilitator, supporter, resource person • Teacher monitors progress to determine when intervention or another approach is required	• Activating student interest and curiosity • Developing creativity and interpersonal skills and strategies • Exploring diverse possibilities • Forming hypotheses and developing concepts • Solving problems • Drawing inferences	Students: • Observing • Investigating • Inquiring and researching • Jigsaw groups • Problem solving • Reading and viewing for meaning • Reflective discussion • Concept mapping	• Active involvement an effective way for students to learn • High degree of differentiation and pursuit of individual interests possible • Excellent facilitation and organizational skills required of teachers • Some difficulty integrating focused instruction and concepts of content
Interactive Instruction	• Student-centred • Teacher forms groups, teaches and guides small-group skills and strategies	• Activating student interest and curiosity • Developing creativity and interpersonal skills and strategies • Exploring diverse possibilities • Forming hypotheses and developing concepts • Solving problems • Drawing inferences	Students: • Discussing • Sharing • Generating alternative ways of thinking and feeling • Decision making • Debates • Role-playing • Panels • Brainstorming • Peer conferencing • Collaborative learning groups • Problem solving • Talking circles • Interviewing • Peer editing	• Increase of student motivation and learning through active involvement in groups • Key to success is teacher's knowledge and skill in forming groups, instructing, and guiding group dynamics • Effective in assisting students' development of life skills in cooperation and collaboration

(continued)

Instructional Approaches: Roles, Purposes and Methods: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 2-5 to 2-6.

Instructional Approaches: Roles, Purposes, and Methods *(continued)*				
Instructional Approaches	**Roles**	**Purposes/Uses**	**Methods**	**Advantages/ Limitations**
Experiential Learning	• Student-centred • Teacher's role may be to design the order and steps of the process	• Focusing on processes of learning rather than products • Developing students' knowledge and experience • Preparing students for direct instruction	Students: • Participating in learning activities • Field trips • Simulations • Primary research • Games • Focused imaging • Role-playing • Surveys • Sharing observations and reflections • Reflecting critically on experiences • Developing hypotheses and generalizations in new situations	• Increase in student understanding and retention • Additional resources and time required for hands-on learning
Independent Study	• Student-centred • Teacher's role to guide or supervise students' independent study, teach knowledge, skills, and strategies that students require for independent learning, and provide adequate practice	• Accessing and developing student initiative • Developing student responsibility • Developing self-reliance and independence	Students: • Inquiry and research projects using a variety of approaches and methods • Computer-assisted instruction • Essays and reports • Study guides • Learning contracts • Homework • Learning centres	• Students grow as independent, lifelong learners • Student maturity, knowledge, skills, and strategies important to success • Student access to resources essential • Approach flexible (may be used with individual students while other students use other approaches)

Linking Instructional Approaches with Specific Instructional Strategies

The interactions of the five instructional approaches just discussed can be linked to more specific strategies commonly found within this curriculum document. Although not exhaustive, the instructional strategies that follow may be used with Senior 3 Current Topics in the Sciences as starting points toward a broader array of strategically used classroom learning experiences with students.

Direct Instruction

- **Teacher demonstrations:** Demonstrations, such as discrepant events, may be used to arouse student interest and allow for visualization of phenomena. Demonstrations can activate prior knowledge and generate discussion around learning outcomes.
- **Community connections:** Field trips and guest speakers may provide students with opportunities to see science applied in their community and in local natural environments.
- **Prior knowledge activities:** Students learn best when they are able to relate new knowledge to what they already know. Brainstorming, KWL (Know, Want to know, Learned) charts, and Listen-Think-Pair-Share (see *SYSTH*) are just a few of the strategies that may be used to activate and assess students' prior knowledge.

Indirect Instruction

- **Class discussion (teacher facilitated):** Discussions may be used in a variety of ways. They may spark interest in a topic or learning outcome, activate prior knowledge by inviting speculation on why certain events occur, or generate ideas for solutions to problems.
- **Collaborative teamwork:** Instructional strategies, such as the Jigsaw or Roundtable (see *SYSTH*), encourage students to learn from one another and to develop teamwork skills. The use of cooperative learning activities may lead to increased understanding of content and improved thinking skills.

Interactive Instruction

- **Class discussion (student facilitated):** Student-led discussions may be used with groups of students who are amenable to this form of interaction once procedures have been well developed in advance. They may spark interest in a topic or learning outcome, activate prior knowledge by inviting speculation on why certain events occur, or generate ideas for solutions to problems.
- **Debates:** Debates draw upon students' own positions on STSE issues. When carefully structured, debates may be used to encourage students' consideration of societal concerns and the opinions of others, and improve their communication and research skills.

Experiential Learning

- **Student research/reports:** Learning projects that involve student research are among the most effective ways to individualize instruction in a diverse classroom. These learning activities provide students with opportunities to develop their research skills as they gather, process, and evaluate information.
- **Problem-based learning (PBL):** PBL is a curricular design that centres on an authentic problem. Students are assigned roles and presented with a problem that has no single, clear-cut solution. Students acquire content knowledge as they work toward solving the problem.
- **Journal writing:** Science journal writing allows students to explore and record various aspects of their experiences in science class. By sorting out their thoughts on paper or thinking about their learning (metacognition), students are better able to process what they are learning.
- **Laboratory activities:** Laboratory activities, whether student- or teacher-designed, provide students with opportunities to apply their scientific knowledge and skills related to a group of learning outcomes. Students will appreciate the hands-on experience of *doing* science as opposed to a sense of just learning about science.

Independent Study

- **WebQuests:** A WebQuest is an inquiry-oriented activity in which most or all of the information used by learners comes from resources on the Internet. WebQuests are designed to use learners' time well, to focus on using information rather than looking for it, and to support learners' thinking at the levels of analysis, synthesis, and evaluation.
- **Visual displays:** When students create visual displays, they make their thinking visible. Generating diagrams, concept maps, posters, and models provides students with opportunities to represent abstract information in a more concrete form.

Phases of Learning

When preparing instructional plans and goals, many teachers find it helpful to consider three learning phases:

- **activating** (preparing for learning)
- **acquiring** (integrating and processing learning)
- **applying** (consolidating learning)

These phases are not entirely linear but are a useful way of thinking and planning. A variety of activating, acquiring, and applying strategies are discussed in the *Senior Years Science Teachers' Handbook* (Manitoba Education and Training).

Activating (Preparing for Learning)

One of the strongest indications of how well students comprehend new information is their prior knowledge of the subject. Some educators observe that more student learning occurs during this activating phase than at any other time. In planning instruction and assessment, teachers develop student learning experiences and select strategies for activating their students' prior knowledge. These learning experiences provide information about the extent of students' prior knowledge of the topic to be studied, their knowledge of and familiarity with the forms of media to be used, and their knowledge of and proficiency in applying skills for learning and using these forms.

Learning experiences that draw on students' prior knowledge

- help students relate new information, skills, and strategies to what they already know and can do (for example, if a text includes unfamiliar vocabulary, students may not recognize the connection between what they know and the new material being presented)
- allow teachers to recognize misconceptions that might make learning difficult for students
- allow teachers to augment and strengthen students' knowledge base when students do not possess adequate prior knowledge and experience to engage with new information and ideas
- help students recognize gaps in their knowledge
- stimulate curiosity and initiate the inquiry process that will direct learning

Acquiring (Integrating and Processing Learning)

In the second phase of learning, students engage with new information and integrate it with what they already know, adding to and revising their previous knowledge. Part of the teacher's role in this phase is to present this new information or to help students access it from various resources.

Since learning is an internal process, however, facilitating learning requires more of teachers than simply presenting information. In the acquiring phase, teachers instruct students in strategies that help them make meaning of information, integrate it with what they already know, and express their new understanding. In addition, teachers monitor these processes to ensure that learning is taking place, using a variety of instruments, tools, and strategies such as observations, conferences, and examination of student work.

Phases of Learning: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 2-6 to 2-8.

In practice, within an actual lesson or unit, the acquiring phase of learning may include a series of steps and strategies, such as

- setting the purpose (for example, discrepant events, lesson overviews)
- presenting information (for example, lab demonstrations, guest speakers, mini-lessons, active reading)
- processing information (for example, note making, group discussions, logs, visual representations)
- modelling (for example, role-playing, demonstrations)
- checking for understanding (for example, quizzes, informal conferences)

Applying (Consolidating Learning)

New learning that is not reinforced is soon forgotten. The products and performances by which students demonstrate new learning are not simply required for assessment; they have an essential instructional purpose in providing students with opportunities to demonstrate and consolidate their new knowledge, skills and strategies, and attitudes. Students also need opportunities to reflect on what they have learned and to consider how new learning applies to new situations. By restructuring information, expressing new ideas in another form, or integrating what they have learned in science with concepts from other subject areas, students strengthen and extend learning.

To ensure that students consolidate new learning, teachers plan various learning experiences involving

- reflection (for example, journals, Exit Slips)
- closure (for example, sharing of products, debriefing on processes)
- application (for example, inquiry, design process)

Differentiating Instruction

How can Senior Years science teachers meet each student's learning requirements and still make learning experiences challenging and meaningful for all? One way to help all students achieve the identified student learning outcomes is to differentiate the instructional strategies.

Through differentiating instruction, teachers can

- activate students' prior knowledge
- accommodate multiple intelligences and the variety of learning and thinking approaches
- help students interpret, apply, and integrate information
- facilitate the transfer of knowledge, skills and strategies, and attitudes to students' daily lives
- challenge students to realize academic and personal progress and achievement

Differentiating instruction does not mean offering different programming to each student. Classroom experiences can be differentiated by offering students choices and by varying instructional and assessment strategies to provide challenging and effective learning experiences for all. Ideas and strategies for differentiating instruction are provided in *Senior Years Science Teachers' Handbook* (Manitoba Education and Training) and in *Success for All Learners* (Manitoba Education and Training).

Promoting Strategic Learning

Many of the tasks science students perform are problem-solving tasks, such as finding sources of information for a decision-making activity or developing a method for an inquiry task. To solve problems, students require a strategic mindset. When confronted with a problem, students survey a number of possible strategies, select the one that seems likely to work best for the situation, and try an alternative method if the first one does not produce results.

Strategic learners in the sciences need to have not only a strategic mindset, but also a repertoire of strategies for making meaning, for processing information, and for expressing ideas and information effectively. Whereas skills are largely unconscious mental processes that learners use in accomplishing learning tasks, strategies are systematic and conscious plans, actions, and thoughts that learners select or invent and adapt to each task. Strategies are often described as "knowing what to do, how to do it, when to do it, and why it is useful."

Scaffolding: Supporting Students in Strategic Learning

Many scientific tasks involve a complex interaction of skills. The most effective way to learn, however, is not by breaking down the tasks into manageable parts and teaching the skills separately and in isolation. In fact, this approach may be counter-productive. Purcell-Gates uses the analogy of learning to ride a bicycle, a skill that requires children to develop an intuitive sense of balance while also learning to pedal and steer. Children do not learn to ride a bicycle by focusing on only one of these skills at a time. Instead, they observe others who can ride a bicycle successfully, and then make an attempt themselves. In the early stages of learning to ride, a child counts on someone to provide support—to hold the bicycle upright while the child mounts, to keep a hand on the seat to stabilize the bicycle for the first few metres, and to coach and encourage. Gradually, these supports are withdrawn as the rider becomes more competent. Eventually, the process becomes automatic, and the rider is no longer aware of the skills being performed.

Providing this sort of support in teaching is called "scaffolding" and is based on the work of Wood, Bruner, and Ross. Teachers scaffold by

- structuring tasks so that learners begin with something they can do
- reducing the complexity of tasks
- calling students' attention to critical features of the tasks
- modelling steps
- providing sufficient guided and independent practice

Promoting Strategic Learning: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Section 2-8 to 2-10.

In a sense, each learning strategy is an external support or scaffold. At first, working with a new strategy may be challenging and the main focus of students' attention. Eventually, students use the strategy automatically and rely on it as a learning tool. Students gradually internalize the process of the strategy. They begin to adjust and personalize the process and to apply the thinking behind the strategy automatically.

In strategic instruction, teachers observe and monitor students' use of a strategy for a time, intervening where necessary. Students vary in the length of time they require scaffolding. In this respect, strategic instruction is also a useful tool for differentiation. Struggling learners may work with simplified versions of a strategy, and they may continue to use the supports of a strategy (for example, a graphic organizer for laboratory reports) after other students have internalized the process.

Strategic instruction works best when teachers pace the instruction of new strategies carefully (so that students have time to practise each one), and when they teach a strategy in the context of a specific task of relevant scientific experience.

Learning Resources

Traditionally, the teaching of science in Senior Years has largely been a textbook-centred exercise. The use of a single textbook as the sole resource for the teaching and learning of science severely restricts the development of knowledge, skills and strategies, and attitudes that are critical for today's students. Furthermore, it promotes the idea that all answers are enshrined in a textbook. The successful implementation of Senior 3 Current Topics in the Sciences depends on a resource-based learning approach in which textbooks are used only as one of many reference sources. Research suggests that we should provide a wide range of learning resources for structuring teaching and learning experiences. These include human resources, textbooks, magazines/journals, films, audio and video recordings, computer-based multimedia resources, the Internet, and other materials.

Resources referenced in this curriculum include print reference materials such as *Senior Years Science Teachers' Handbook: A Teaching Resource (SYSTH)* (Manitoba Education and Training) and *Science Safety: A Kindergarten to Senior 4 Resource Manual for Teachers, Schools, and School Divisions* (Manitoba Education and Training).

The choice of learning resources, such as textbook(s), multimedia learning resources, including video, software, CD-ROMs, microcomputer-based laboratory (MBL) probeware, calculator-based laboratory (CBL) probeware, and the websites on the Internet, will depend on the unit of study, the local situation, the reading level of students, background of the teacher, community resources, and availability of other materials. A concerted effort should be made to use appropriate learning resources from a wide variety of sources, as not all curricular outcomes can be achieved by using any one resource in the study of a particular theme.

Implementing the Curriculum

Science curricula in the past have focused primarily on presenting a breadth of knowledge (that is, a large amount of content) deemed essential. While the Senior 3 Current Topics in the Sciences curriculum continues to be concerned with students acquiring relevant knowledge, it is equally concerned both with fostering the development of various skills (context-based process skills, as well as skills in decision making, problem solving, laboratory experimentation, critical thinking, and independent learning), and with effecting a change of attitude. A strong focus of this curriculum is to link science to the experiential life of the student.

By offering a multidisciplinary focus, Senior 3 Current Topics in the Sciences provides a solid foundation for scientific literacy. The curriculum, consisting of four general learning outcomes (GLOs), each with a number of specific learning outcomes (SLOs), will build upon what students know and are able to do as a result of their studies in Kindergarten to Senior 2 science. (Refer to Topic Chart for Kindergarten to Senior 2 Science at the end of Section 1.)

Senior 3 Current Topics in the Sciences assumes 110 hours of instructional time.

Unit Development

Senior 3 Current Topics in the Sciences is driven by learning outcomes and process. This design empowers teachers to plan appropriate learning experiences based on the nature of their students, school, and community. Teachers are encouraged to seek their own comfort level with the new curriculum, to share approaches and experiences with colleagues, and to use an integrated interdisciplinary focus to develop and extend student experiences and understandings in new ways. The thematic approach to integrated instruction will allow teachers to work closely together as they develop units that extend across disciplines (Willis).

Working with bigger ideas will allow a more in-depth inquiry. Organizing units around a problem or theme will generally present information in the context of real-world applications (Willis). Students will be presented with opportunities to uncover concepts from each of the sciences during the year in a substantial way and to make coherent connections between them.

> Science deals with major themes in which people are already interested or can readily be interested: life and living things, matter, the Universe, information, the "made-world." A primary reason, therefore, for teaching science to young people is to pass on to them some of this knowledge about the material world, simply because it is both interesting and important—and to convey the sense of excitement that scientific knowledge brings (Millar and Osborne 7).

Choosing a Current Topic

The flexibility of Senior 3 Current Topics in the Sciences allows teachers to design meaningful and engaging interdisciplinary units based on current scientific issues and developments. It is suggested that teachers develop three or four units for this course. The first step in the development of a unit is choosing a topic.

Choosing an effective topic is critical to the success of Senior 3 Current Topics in the Sciences. An engaging topic should have one or more of the following characteristics:

- is age appropriate and accessible to a diversity of learning styles, interests, and abilities
- is meaningful and engaging to students
- is of current societal and scientific significance
- incorporates a significant number of the student learning outcomes identified for this course
- connects a range of science disciplines
- is framed within the context of a question or problem
- provides opportunities for in-depth student-driven inquiry
- provides opportunities for both knowledge acquisition and skill development to arise naturally in context
- will result in a performance-based activity as a culminating experience

Teachers may decide to choose a topic from the suggestions listed below, develop a topic based on one of their own strengths or interests, or involve students in brainstorming a current scientific topic of interest that includes a significant treatment of scientific ideas, perspectives, content, and processes.

Possible Current Themes or Topics

- Are We Alone in the Universe?
- Biotechnology: The Good, the Bad, and the Unknown
- What in the World Is Climate Change?
- Cloning: What Can We Do and What Should We Do?
- Forensic Sciences: Crime Scene Investigation
- Where Will the Next Earthquake Occur?
- Energy Today and Tomorrow: Can We Avoid Large-Scale Blackouts?
- Environmental Interactions
- The Evolution of the Human Species: Where Did We Come From? Where Are We Going?
- Global Warming: Fact or Fiction?
- The Human Endeavour in Space
- Medical Technologies: What's New?
- Great Geological Controversies: Expanded Earth or Plate Tectonics?
- The "Snowball Earth": Has the Entire Planet Frozen over in the Past?
- Is the World Doing Enough to Reduce Pollution?
- Recycling: Is It Working?
- Science of Music: Why Do We Like It So Much?
- Sports Science: How Do Science and Technology Aid the Athlete?
- Stem-Cell Research: Ideas and Issues
- Technologies of the Future: What Was Predicted in 1950 and Where Are We Now?
- Transportation in the Future: Getting From A to B
- Water: Will We Ever Run Out?
- Causes and Consequences of Wildfires
- Human Population Cycles: Is There Room for Us All?

Senior 3 Current Topics in the Sciences welcomes and encourages the input of students in the choice of topics and in topic development. Teachers may choose to involve students in the development of a thematic unit. A brainstorming session with the class could allow students to generate topics of interest, from which a unit may be planned, or develop the essential understandings within the chosen unit.

The Forensic Sciences topic has been developed as a sample unit for teachers to consider for use in implementing this curriculum. For a detailed discussion of suggested elements for effective unit design, see Appendix 1. Teachers are encouraged to consult this section of the document before engaging in unit design.

SECTION 3: ASSESSMENT IN SENIOR 3 CURRENT TOPICS IN THE SCIENCES

ASSESSMENT IN SENIOR 3 CURRENT TOPICS IN THE SCIENCES

Classroom Assessment

Classroom assessment is an integral part of science instruction. Assessment is the "systematic process of gathering information about what a student knows, is able to do, and is learning to do" (Manitoba Education and Training, *Reporting on Student Progress and Achievement* 5). The primary purpose of classroom assessment is not to evaluate and classify student performance, but to inform teaching and improve learning, and to monitor student progress in achieving year-end learning outcomes.

> Rather then emphasizing the recall of specific, detailed and unrelated "facts," [assessment in science] should give greater weight to an assessment of a holistic understanding of the major scientific ideas and a critical understanding of science and scientific reasoning (Millar and Osborne 25).

Classroom assessment is broadly defined as any activity or experience that provides information about student learning. Teachers learn about student progress not only through formal tests, examinations, and projects, but also through moment-by-moment observations of students in action. They often conduct assessment through instructional activities.

Much of students' learning is internal. To assess students' science knowledge, skills and strategies, and attitudes, teachers require a variety of tools and approaches. They ask questions, observe students engaged in a variety of learning activities and processes, and examine student work in progress. They also engage students in peer-assessment and self-assessment activities. The information that teachers and students gain from assessment activities informs and shapes what happens in the classroom. Assessment always implies that some action will follow.

To determine whether student learning outcomes have been achieved, student assessment must be an integrated part of teaching and learning. Assessment of student learning involves careful planning and systematic implementation.

Planning for Assessment

Assessment purposes, approaches, and tools should be developed with instructional approaches during the planning of the unit. In developing assessment tasks and methods, teachers determine

- what they are assessing
- why they are assessing
- how the assessment information will be used
- who will receive the assessment information
- what assessment activities or tasks will allow students to demonstrate their learning in authentic ways

Characteristics of Effective Assessment

Effective assessment helps focus effort on implementing strategies to facilitate learning both inside and outside the classroom. Effective assessment is

- congruent with instruction and integral to it
- ongoing and continuous
- based on authentic tasks and meaningful science-learning processes and contexts
- based on criteria that students know and understand and appeals to their strengths
- a collaborative process involving students
- multi-dimensional and uses a wide range of tools and methods
- focused on what students have learned and can do

A detailed discussion of these seven characteristics of effective assessment follows.

Effective Assessment Is Congruent with Instruction and Integral to It

Assessment requires teachers to be aware continually of the purpose of instruction: What do I want my students to learn? What can they do to show that they have learned it?

How teachers assess depends on what they are assessing—whether they are assessing declarative knowledge, procedural knowledge, or attitudes and habits of mind.

- **Declarative knowledge:** Declarative knowledge is the most straightforward dimension of learning to measure using traditional tools—if teachers wish to measure fact-based recall. The purpose of fostering scientific literacy, however, is not met if students simply memorize the declarative knowledge related to science. What is more important is whether students understand and are able to apply this knowledge. For example, it is more important that they understand the purposes and effects of biodiversity, that they respond to and interpret what biodiversity means for them personally and environmentally, and that they use terminology with ease to enrich their scientific communication skills, and represent—rather than reproduce—a definition of biodiversity. The challenge teachers face is to design tools that test the application of declarative knowledge.
- **Procedural knowledge:** Tools that are designed to test declarative knowledge cannot effectively assess skills and processes. For example, rather than trying to infer student processes by looking at final products, teachers assess procedural knowledge by observing students in action, by discussing their strategies with them in conferences and interviews, and by gathering data from student reflections such as journals.
- **Attitudes and habits of mind:** Attitudes and habits of mind cannot be assessed directly. They are implicit in what students do and say. Assessment tools typically describe the behaviours that reflect the attitudes and habits of literate individuals. They identify the attitudes and habits of mind that enhance science-related language learning and use, and provide students with the means to reflect on their own internal processes. For example, rather than assigning global marks for class participation, teachers assess learning outcomes related to students' effective contributions to large and small groups.

Characteristics of Effective Assessment: Adapted from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998) Assessment-3 to -9.

Assessment is intended to inform students of the programming emphases and to help them focus on important aspects of learning. If teachers assess only the elements that are easiest to measure, students may focus only on those things. For example, if science courses place a high value on collaboration, creativity, and divergent thinking (learning outcomes that may be more difficult to measure), then assessment tools and processes must reflect those values. The ways teachers assess (what and how) inform students of what is considered important in learning.

Effective Assessment Is Ongoing and Continuous

Assessment that is woven into daily instruction offers students frequent opportunities to gain feedback, to modify their learning approaches and methods, and to observe their progress. Teachers provide informal assessment by questioning students and offering comments. They also conduct formal assessments at various stages of a project or unit of study.

Continuous assessment provides ongoing opportunities for teachers to review and revise instruction, content, process emphases, and learning resources.

Effective Assessment Is Based on Authentic Tasks and Meaningful Science-Learning Processes and Contexts

Assessment tasks in science should be authentic and meaningful—tasks worth mastering for their own sake rather than tasks designed simply to demonstrate student proficiency for teachers and others. Through assessment, teachers discover whether students can use knowledge, processes, and resources effectively to achieve worthwhile purposes. Therefore, teachers design tasks that replicate the context in which knowledge will be applied in the world beyond the classroom.

For example, authentic science writing tasks employ the forms used by a wide range of people (for example, scientists, journalists, filmmakers, poets, novelists, publicists, speakers, technical writers, engineers, and academics). As often as possible, students write, speak, or represent their ideas for real audiences and for real purposes. In developing assessment tasks, teachers may consider providing students with the resources people use when performing the same tasks in real-life situations related to issues in science.

Authentic assessment tasks are tests not only of the information students possess, but also of the way their understanding of a subject has deepened, and of their ability to apply learning. They demonstrate to students the relevance and importance of learning. Performance-based tests are also a way of consolidating student learning. The perennial problem teachers have with "teaching to the test" is of less concern if tests are authentic assessments of student knowledge, skills and strategies, and attitudes.

Effective Assessment Is Based on Criteria That Students Know and Understand and Appeals to Their Strengths

Assessment criteria must be clearly established and made explicit to students before an assignment or a test so that students can focus their efforts. In addition, whenever possible, students need to be involved in developing assessment criteria. Appendix 8: Developing Assessment Rubrics in Science describes a process for creating assessment rubrics in collaboration with students.

Students should also understand clearly what successful accomplishment of each proposed task looks like. Models of student work from previous years and other exemplars assist students in developing personal learning goals.

Each assessment task should test only those learning outcomes that have been identified to students. This means, for example, that laboratory skills tests need to be devised and marked to gather information about students' laboratory skills, not their ability to express ideas effectively in writing a laboratory report.

Effective Assessment Is a Collaborative Process Involving Students

The ultimate purpose of assessment is to enable students to assess themselves. The gradual increase of student responsibility for assessment is aimed at developing students' autonomy as lifelong learners. Assessment should decrease, rather than foster, students' dependence on teachers' comments for direction in learning and on marks for validation of their accomplishments.

Assessment enhances students' metacognition. It helps them make judgements about their own learning, and provides them with information for goal setting and self-monitoring.

Teachers increase students' responsibility for assessment by

- requiring students to select the products and performances to demonstrate their learning
- involving students in developing assessment criteria whenever possible (This clarifies the goals of a particular assignment and provides students with the vocabulary to discuss their own work.)
- involving students in peer assessment, informally through peer conferences and formally through using checklists
- having students use tools for reflection and self-assessment at every opportunity (for example, self-assessment checklists, journals, identification and selection of goals, and self-assessment of portfolio items)
- establishing a protocol for students who wish to challenge a teacher-assigned mark (Formal appeals are valuable exercises in persuasive writing, and provide opportunities for students to examine their performance in light of the assessment criteria.)

Effective Assessment Is Multi-dimensional and Uses a Wide Range of Tools and Methods

Assessment in science must recognize the complexity and holistic nature of learning for scientific literacy. To compile a complete profile of each student's progress, teachers gather data using many different means over numerous occasions. Student profiles may involve both students and teachers in data gathering and assessment.

The following chart identifies areas for assessment and some suggested assessment instruments, tools, and methods.

<table>
<tr><th colspan="4">Data-Gathering Profile</th></tr>
<tr><th colspan="2">Observation of Processes</th><th colspan="2">Observation of Products and Performances</th></tr>
<tr>
<td>Teacher:
• checklists
• conferences and interviews
• anecdotal comments and records
• reviews of drafts and revisions
• oral presentations
• rubrics and marking scales</td>
<td>Students:
• journals
• self-assessment instruments and tools (e.g., checklists, rating scales, progress charts)
• peer-assessment instruments and tools (e.g., peer conference records, rating scales)</td>
<td>Teacher:
• written assignments
• demonstrations
• presentations
• seminars
• projects
• portfolios
• student journals and notebooks
• checklists
• rubrics and marking scales</td>
<td>Students:
• journals
• self-assessment instruments and tools
• peer-assessment instruments and tools
• portfolio analysis</td>
</tr>
<tr><th colspan="2">Classroom Tests</th><th colspan="2">Divisional and Provincial Standards Tests</th></tr>
<tr>
<td>Teacher
• paper-and-pencil tests (e.g., teacher-made tests, unit tests, essay-style tests)
• performance tests and simulations
• rubrics and marking scales</td>
<td>Students:
• journals
• self-assessment instruments and tools</td>
<td colspan="2">Teacher marker:
• rubrics and marking scales</td>
</tr>
</table>

Effective Assessment Focuses on What Students Have Learned and Can Do

Assessment must be equitable; it must offer opportunities for success to every student. Effective assessment demonstrates the knowledge, skills and attitudes, and strategies of each student and the progress the student is making, rather than simply identifying deficits in learning.

To assess what students have learned and can do, teachers need to use a variety of strategies and approaches such as the following:

- Use a wide range of instruments to assess the multi-dimensional expressions of each student's learning, avoiding reliance upon rote recall or memorization.
- Provide students with opportunities to learn from feedback, to refine their work, and to recognize that not every assignment will be successful, nor will it become part of a summative evaluation.
- Examine several pieces of student work in assessing any particular learning outcome to ensure that data collected are valid bases for making generalizations about student learning.
- Develop complete student profiles by using information from both learning outcome-referenced assessment, which compares a student's performance to predetermined criteria, and self-referenced assessment, which compares a student's performance to her or his prior performance.
- Avoid using assessment for purposes of discipline or classroom control. Ryan, Connell, and Deci found that assessment that is perceived as a tool for controlling student behaviour, meting out rewards and punishments rather than providing feedback on student learning, reduces student motivation.

Students are sometimes assigned a mark of zero for incomplete work. Averaging a zero into the student's mark, however, means the mark no longer communicates accurate information about the student's achievement of science learning outcomes. Unfinished assignments signal personal or motivational problems that need to be addressed in appropriate and alternative ways.

- Allow students, when appropriate and possible, to choose how they will demonstrate their competence.
- Use assessment tools appropriate for assessing individual and unique products, processes, and performances.

Managing Classroom Assessment

Assessment is one of the greatest challenges science teachers face. The practices that make science classrooms vital and effective—promoting student choice, assessing processes, and assessing the subjective aspect of learning—make assessment a complex matter.

Systems and supports that may assist teachers in managing assessment include

- dispensing with ineffectual means of assessment
- using time savers
- sharing the load
- taking advantage of technology
- establishing systems of recording assessment information

A discussion of these suggestions follows.

Dispensing with Ineffectual Means of Assessment

Teachers need to question the efficacy, for example, of writing lengthy commentaries on summative assessment of student projects. Detailed comments are best

- provided as formative assessment, when students can make immediate use of the feedback
- shared orally in conferences, which provide opportunities for student-teacher discussion

The time spent in assessment needs to be learning time, both for teacher and student.

Using Time Savers

Many effective assessment tools are time savers. Developing checklists and rubrics is time-consuming; however, well-written rubrics may eliminate the need to write extensive comments, and may mean that student performances can be assessed largely during class time.

Sharing the Load

While the ultimate responsibility for assessment rests with the teacher, student self-assessment also provides a wealth of information. Collaborating with students to generate assessment criteria is part of effective instruction. Senior 3 students may develop checklists and keep copies of their own goals in an assessment binder for periodic conferences. Students may be willing to contribute work samples to be used as models in other classes.

Collaborating with other teachers in creating assessment tools saves time and provides opportunities to discuss assessment criteria.

Taking Advantage of Technology

Electronic tools (for example, audiotapes, videotapes, and computer files) can assist teachers in making and recording observations. Word processors allow teachers to save, modify, and reuse task-specific checklists and rubrics.

Managing Classroom Assessment: Adapted from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998) Assessment-9 to -10.

Establishing Systems for Recording Assessment Information

Collecting data from student observations is especially challenging for Senior Years teachers, who may teach several classes of students in a given semester or term. Teachers may want to identify a group of students in each class for observation each week. Binders, card files, and electronic databases are useful for record keeping, as are self-adhesive notes recording brief observations on student files, which can later be transformed into anecdotal reports.

Teachers may also want to develop comprehensive forms for listing the prescribed learning outcomes and for recording data.

Changing Emphases in Assessment

This view of effective assessment in science for Manitoba is reflective of changes in emphases in science education at the national level and is congruent with international changes in science education. The following chart summarizes some changes in the **assessment of student learning**, as envisioned by the *National Science Education Standards* (National Research Council).

Changing Emphases in Assessment of Student Learning

Less Emphasis On		More Emphasis On
Assessing what is easily measured	⇨	Assessing what is most highly valued
Assessing discrete knowledge	⇨	Assessing rich, well-structured knowledge
Assessing scientific knowledge	⇨	Assessing scientific understanding and reasoning
Assessing to learn what students do not know	⇨	Assessing to learn what students do understand
Assessing only achievement	⇨	Assessing achievement and opportunity to learn
End-of-term assessments by teachers	⇨	Students engaged in ongoing assessment of their work and that of others
Development of external assessment by measurements experts alone	⇨	Teachers involved in the development of external assessments

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Types of Assessment

Assessment can be formative, summative, or diagnostic:

- **Formative assessment** is given during the instructional unit and provides students and teachers with information about students' progress in accomplishing identified learning outcomes. Formative assessment also evaluates the effectiveness of instructional programming content, methods, sequence, and pace.
- **Summative assessment** (evaluation) is based on an interpretation of the assessment information collected and is given at the end of an instructional unit. It helps determine the extent of each student's achievement of learning outcomes. Evaluation should be based on a variety of assessment information. Summative assessment is used primarily to measure student achievement, to report to parent(s) or guardian(s), students, and other stakeholders, or to measure the effectiveness of instructional programming.
- **Diagnostic assessment** is given before instruction and determines student understanding of topics before learning takes place.

Assessment Strategies

A range of assessment strategies, such as the following, can be used in the science classroom. The same strategy can be used both for formative and summative assessment, depending on the purpose of the assessment. Teachers are strongly encouraged to develop their own assessment for Senior Years science based on their students' learning requirements and the identified student learning outcomes.

- **Observation:** Observation of students is an integral part of the assessment process. It is most effective when focused on skills, concepts, and attitudes. Making brief notes on index cards, self-adhesive notes, or grids, as well as keeping checklists, helps teachers maintain records of continuous progress and achievement.
- **Interviews:** Interviews allow teachers to assess an individual's understanding and achievement of the student learning outcome(s). Interviews provide students with opportunities to model and explain their understandings. Interviews may be both formal and informal. Posing science-related questions during planned interviews enables teachers to focus on individual student skills and attitudes. Students reveal their thinking processes and use of skills when they are questioned about how they solved problems or answered science questions. Using a prepared set of questions ensures that all interviews follow a similar structure. It is important to keep a record of student responses and/or understandings.
- **Group/peer assessment:** Group assessment gives students opportunities to assess how well they work within a group. Peer assessment gives them opportunities to reflect on each other's work, according to clearly established criteria. During the peer-assessment process, students must reflect on their own understanding in order to evaluate the performance of another student.

Types of Assessment: Adapted from Manitoba Education and Youth, *Senior 2 Science: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Youth, 2003) 48-50.

- **Self-assessment:** Self-assessment is vital to all learning and, therefore, integral to the assessment process. Each student should be encouraged to assess her or his own work. Students apply known criteria and expectations to their work and reflect on results to determine their progress toward the mastery of a specific learning outcome. Participation in setting self-assessment criteria and expectations helps students to see themselves as scientists and problem solvers. It is important that teachers model the self-assessment process before expecting students to assess themselves.
- **Science journal entries:** Science journal writing provides students with opportunities to reflect on their learning and to demonstrate their understanding using pictures, labelled drawings, and words. Journal entries can be powerful tools of formative assessment, allowing teachers to gauge a student's depth of understanding.
- **Rubrics/checklists:** Rubrics and checklists are tools that identify the criteria upon which student processes, performances, or products will be assessed. They also describe the qualities of work at various levels of proficiency for each criterion. Rubrics and checklists may be developed in collaboration with students.
- **Visual displays:** When individuals or groups of students prepare visual displays, they are involved in processing information and producing a knowledge framework. The completed work (e.g., a poster, concept map, diagram, model) is the product that teachers use to determine what their students are thinking.
- **Laboratory reports:** Laboratory reports allow teachers to gauge the ability of students to observe, record, and interpret experimental results. These tools can aid teachers in determining how well students understand the content.
- **Pencil-and-paper tasks:** Quizzes can be used as discrete assessment tools, and tests can be larger assessment experiences. These written tasks may include items such as multiple-choice questions, completion of a drawing or labelled diagram, problem solving, or long-answer questions. Ensure that both restricted and extended expository responses are included in these assessment devices.
- **Research reports/presentations:** Research projects allow students to achieve the learning outcomes in individual ways. Assessment should be built into the project at every stage, from planning, to researching, to presenting the finished product.
- **Performance assessments/student demonstrations:** Performance tasks provide students with opportunities to demonstrate their knowledge, thinking processes, and skill development. The tasks require the application of knowledge and skills related to a group of learning outcomes. Performance-based tests do not test the information students possess, but rather the way their understanding of a subject has been deepened and their ability to apply their learning in a simulated performance. A scoring rubric that includes a scale for the performance of the task helps organize and interpret evidence. Rubrics allow for a continuum of performance levels associated with the task being assessed.

Performance-Based Assessment Approaches

The following performance-based assessment approaches and strategies can be used to assess student knowledge and skills:

- **Interpreting media reports of science:** Short pieces extracted from newspapers could be used to assess whether students understand the scientific content of the piece; whether they can identify and evaluate the possible risks and quality of the evidence presented; whether they can offer well-thought-out reactions to the claims; and, finally, whether they can give their opinions about future action that could be taken by individuals, government, or other bodies.
- **Demonstrating understanding of the major explanatory stories of science:** Questions should seek to examine, for instance, whether students have understood what the particle model of matter is; whether they can give a short account of it; whether they can use it to explain everyday phenomena; and whether they can explain why it is an important idea in science.
- **Asking and answering questions based on data:** Such questions should assess students' ability to represent data in a variety of ways; to formulate and interpret the messages that can be extracted from data; and to detect errors and dishonesty in the way data are presented or selected. The ability to manipulate and interpret data is a core skill that is of value, not only in science, but also in a wide range of other professions and contexts.
- **Recognizing the role of evidence:** At the heart of scientific rationality is a commitment to evidence. Contemporary science confronts the modern citizen with claims that are contested and uncertain. Questions based on historical or contemporary examples can be used to investigate students' understanding of the role of evidence in resolving competing arguments between differing theoretical accounts.

Performance-Based Assessment Approaches: Adapted from Robin Millar and Jonathan Osborne, eds., *Beyond 2000: Science Education for the Future* (London, UK: King's College, 1998) 26. Adapted by permission of the authors.

SECTION 4: DOCUMENT ORGANIZATION

DOCUMENT ORGANIZATION

Document Organization and Format

The suggestions for instruction and assessment and the appendices contained within *Senior 3 Current Topics in the Sciences: A Foundation for Implementation* provide teachers and other science educators with a plan for achieving the specific student learning outcomes identified for this curriculum. The document is organized according to, and implementation is primarily driven by, four General Learning Outcomes (GLOs):

- GLO A: Nature of Science and Technology
- GLO B: Science, Technology, Society, and the Environment (STSE)
- GLO C: Scientific and Technological Skills and Attitudes
- GLO D: Essential Concepts

Due to the unique nature of these four foundation areas, there are necessary differences in how each of the GLO sections appears in this document. In keeping with a generally *constructivist* approach to the teaching and learning cycle, teachers will find headings such as **Activating, Acquiring,** and **Applying**. Within each of these are instructional suggestions that offer teachers a range of strategies from which to select appropriate directions with students.

In addition, the appendices comprise information on unit development, teacher support materials related to instruction and assessment, and assessment rubrics. These complementary resources are closely linked to the learning outcomes, and are designed to support, facilitate, and enhance student learning and assessment.

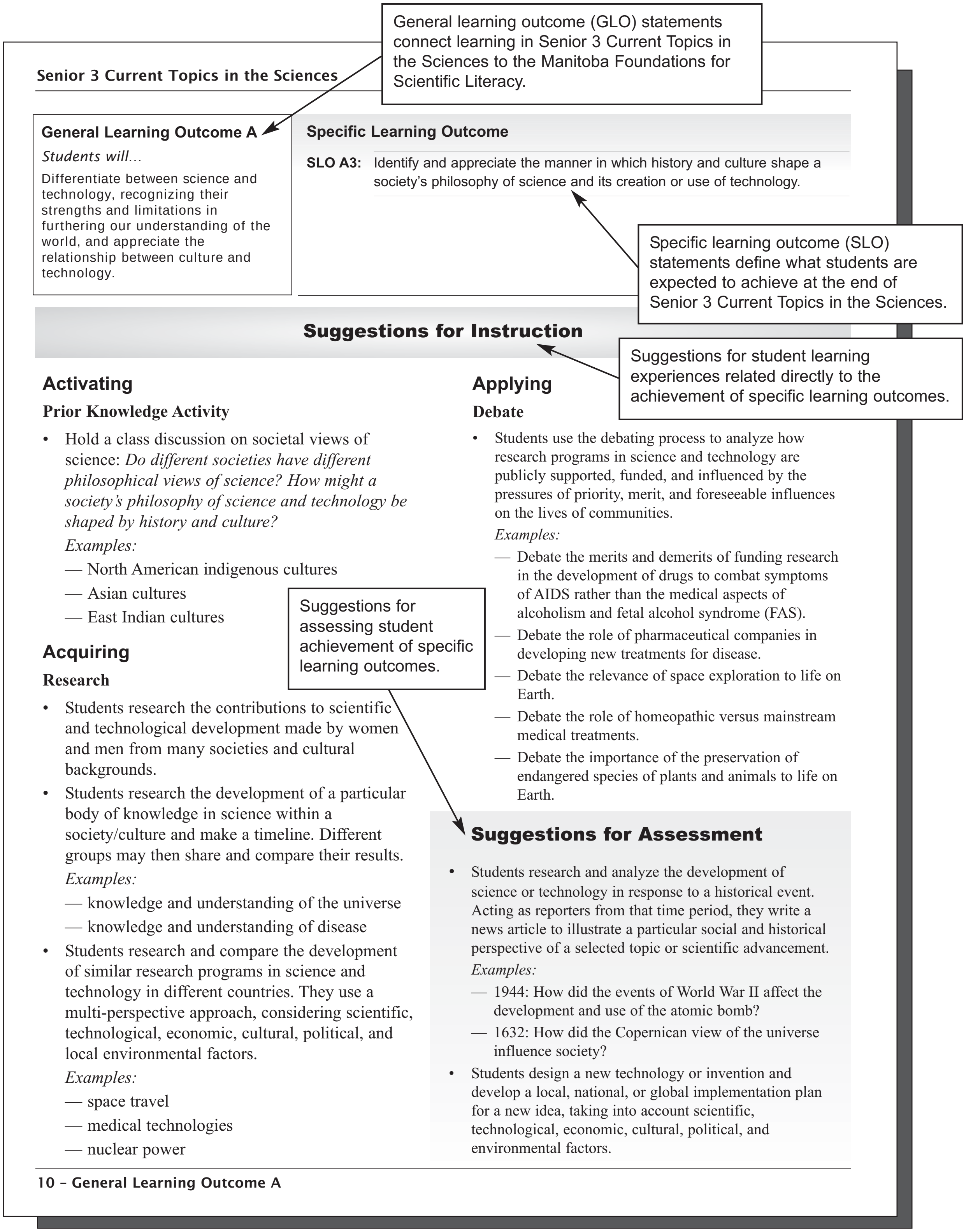
Guide to Reading the Specific Learning Outcomes and the Document Format

The GLO sections are organized as follows:

- The **General Learning Outcomes** identified in the header outline the intended learning to be achieved by the student by the end of the curriculum. The GLOs are supported by the **specific learning outcomes (SLOs)** related to the particular foundation area being addressed.
- The **Suggestions for Instruction** relate directly to the achievement of the specific learning outcome(s) identified at the top of a page.
- The **Suggestions for Assessment** offer strategies for assessing students' achievement of the specific learning outcomes.
- **Teacher Notes** boxes allow for handwritten planning hints, notes on special interest material, and depth of treatment on certain issues related to the learning outcomes. These are incorporated as text boxes throughout.

The pages that follow provide detailed clarification on reading the document format, and are based on a sample, two-page spread from *Senior 3 Current Topics in the Sciences: A Foundation for Implementation*.

Document Format



Senior 3 Current Topics in the Sciences

General Learning Outcome A

Students will...

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- Hold a class discussion on societal views of science: *Do different societies have different philosophical views of science? How might a society's philosophy of science and technology be shaped by history and culture?*

  Examples:
  - — North American indigenous cultures
  - — Asian cultures
  - — East Indian cultures

Acquiring

Research

- Students research the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds.
- Students research the development of a particular body of knowledge in science within a society/culture and make a timeline. Different groups may then share and compare their results.

  Examples:
  - — knowledge and understanding of the universe
  - — knowledge and understanding of disease
- Students research and compare the development of similar research programs in science and technology in different countries. They use a multi-perspective approach, considering scientific, technological, economic, cultural, political, and local environmental factors.

  Examples:
  - — space travel
  - — medical technologies
  - — nuclear power

Applying

Debate

- Students use the debating process to analyze how research programs in science and technology are publicly supported, funded, and influenced by the pressures of priority, merit, and foreseeable influences on the lives of communities.

  Examples:
  - — Debate the merits and demerits of funding research in the development of drugs to combat symptoms of AIDS rather than the medical aspects of alcoholism and fetal alcohol syndrome (FAS).
  - — Debate the role of pharmaceutical companies in developing new treatments for disease.
  - — Debate the relevance of space exploration to life on Earth.
  - — Debate the role of homeopathic versus mainstream medical treatments.
  - — Debate the importance of the preservation of endangered species of plants and animals to life on Earth.

Suggestions for Assessment

- Students research and analyze the development of science or technology in response to a historical event. Acting as reporters from that time period, they write a news article to illustrate a particular social and historical perspective of a selected topic or scientific advancement.

  Examples:
  - — 1944: How did the events of World War II affect the development and use of the atomic bomb?
  - — 1632: How did the Copernican view of the universe influence society?
- Students design a new technology or invention and develop a local, national, or global implementation plan for a new idea, taking into account scientific, technological, economic, cultural, political, and environmental factors.

10 – General Learning Outcome A

General Learning Outcome A	Specific Learning Outcome
Students will… Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.	**SLO A4:** Recognize that science and technology interact and evolve, often advancing one another.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- In a class discussion, produce a web showing the interconnections between science and technology, using specific examples generated by the students.

Acquiring

Development of Concepts

- Students identify, analyze, and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology.

  Examples:

  — Investigate and describe how seismology has assisted geoscientists in furthering our understanding of the Earth's interior through applications such as seismic tomography.

  — How did the development of the telescope alter society's understanding of the universe and humanity's place within it?

  — How did the refinement of X-ray crystallography techniques lead to the determination of the structure of deoxyribonucleic acid (DNA)?

  — How do the following relate or interact: the development of particle accelerators, the discovery of subatomic particles, and the revision of atomic theory?
- Students analyze natural and technological systems to interpret and explain their structure and dynamics.

  Examples:

  — Analyze the numerous steps involved in refining petroleum to obtain gasoline and a variety of additives for car engines.

  — Examine the production of hydroelectricity.

Applying

- Students describe the functioning of domestic, industrial, or medical technologies by identifying the scientific principles contained in their design.

  Examples:

  — What principles of physics are involved in the design and use of technologies related to computerized axial tomography (CAT scan) or magnetic resonance imaging (MRI)?

  — Describe the development of the aerospace industry and the modern airplane.

Teacher Notes

Teacher Notes boxes provide opportunities to annotate and personalize the document. These occur throughout the GLO sections.

SENIOR 3 CURRENT TOPICS IN THE SCIENCES: SUGGESTIONS FOR INSTRUCTION AND ASSESSMENT

Linking General and Specific Learning Outcomes to Suggestions for Instruction and Assessment

In Senior 3 Current Topics in the Sciences, the following four General Learning Outcome (GLO) foundation areas often operate simultaneously, rather than consecutively or in isolation:

- GLO A: Nature of Science and Technology
- GLO B: Science, Technology, Society, and the Environment (STSE)
- GLO C: Scientific and Technological Skills and Attitudes
- GLO D: Essential Concepts

The learning outcomes are listed on the following page.

The unique instructional design of *Senior 3 Current Topics in the Sciences: A Foundation for Implementation* (with its emphasis on local decision making about content) naturally demands a different set of document characteristics than what Manitoba science teachers have grown accustomed to. For instance, this curriculum document *cannot* become operational by beginning with GLO A, and then proceeding to GLO B, and so on. What the document does provide—together with its key support document *Senior Years Science Teachers' Handbook* (Manitoba Education and Training)—are suggestions for instruction and assessment that relate in particular ways to one of the four foundation areas.

Therefore, if teachers are involved in a component of a particular unit that has an emphasis on the nature of science, they will want to consult one or more of the instructional and assessment strategies suggested within the section of this document entitled GLO A: Nature of Science and Technology. If the tasks at hand take more skills or mastery learning-based approaches, teachers will identify productive strategies within the section entitled GLO C: Scientific and Technological Skills and Attitudes.

It is important to recognize that this section of the document also provides a *constructivist approach* to the teaching and learning cycle (Activating, Acquiring, and Applying), and assessment priorities can be summarized as follows:

- Identify the targeted learning outcomes as having come *naturally* from the context of the science content in a unit of study.
- Formulate a set of priorities for teaching and learning.
- Carefully select and implement teaching and learning strategies that will be successful with students and their learning climate.
- Assess, along the way, through observation of processes and student products.
- Record, for reporting purposes, appropriate information for students, their parents, and other educators and stakeholders.

General and Specific Learning Outcomes for Senior 3 Current Topics in the Sciences

GLO A: NATURE OF SCIENCE AND TECHNOLOGY
Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

SLO A4: Recognize that science and technology interact and evolve, often advancing one another.

SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

GLO B: SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT
Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.

SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.

SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.

SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.

SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

GLO C: SCIENTIFIC AND TECHNOLOGICAL SKILLS AND ATTITUDES
Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.

SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.

SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.

SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.

SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.

SLO C5: Work cooperatively with others and value their ideas and contributions.

GLO D: ESSENTIAL CONCEPTS
Explore, understand, and use scientific knowledge in a variety of contexts.

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.

SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

SENIOR 3 CURRENT TOPICS IN THE SCIENCES: SUGGESTIONS FOR INSTRUCTION AND ASSESSMENT

Linking General and Specific Learning Outcomes to Suggestions for Instruction and Assessment

In Senior 3 Current Topics in the Sciences, the following four General Learning Outcome (GLO) foundation areas often operate simultaneously, rather than consecutively or in isolation:

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Therefore, if teachers are involved in a component of a particular unit that has an emphasis on the nature of science, they will want to consult one or more of the instructional and assessment strategies suggested within the section of this document entitled GLO A: Nature of Science and Technology. If the tasks at hand take more skills or mastery learning-based approaches, teachers will identify productive strategies within the section entitled GLO C: Scientific and Technological Skills and Attitudes.

It is important to recognize that this section of the document also provides a *constructivist approach* to the teaching and learning cycle (Activating, Acquiring, and Applying), and assessment priorities can be summarized as follows:

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- Formulate a set of priorities for teaching and learning.
- Carefully select and implement teaching and learning strategies that will be successful with students and their learning climate.
- Assess, along the way, through observation of processes and student products.
- Record, for reporting purposes, appropriate information for students, their parents, and other educators and stakeholders.

General and Specific Learning Outcomes for Senior 3 Current Topics in the Sciences

GLO A: NATURE OF SCIENCE AND TECHNOLOGY
Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

SLO A4: Recognize that science and technology interact and evolve, often advancing one another.

SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

GLO B: SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT
Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.

SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.

SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.

SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.

SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

GLO C: SCIENTIFIC AND TECHNOLOGICAL SKILLS AND ATTITUDES
Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.

SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.

SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.

SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.

SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.

SLO C5: Work cooperatively with others and value their ideas and contributions.

GLO D: ESSENTIAL CONCEPTS
Explore, understand, and use scientific knowledge in a variety of contexts.

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.

SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

General Learning Outcome A

Nature of Science and Technology

GLO A

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Overview

Students learn that science and technology are creative human activities with long histories in all cultures.

Science is a way of learning about the universe. This learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over that evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science presently argue that there is no definable, set procedure for conducting a scientific investigation. Rather, they see science as driven by a combination of theoretical concerns, knowledge, experiments, and processes anchored in the physical world.

Technology results mainly from proposing solutions to problems arising from human attempts to adapt to the external environment. "Technology" refers to much more than the knowledge and skills related to devices such as computers, peripherals, and their applications.

Technology is based on the knowledge of concepts and skills from many disciplines (including science), and is the application of this knowledge to meet an identified need or to solve a problem using materials, energy, and tools (including computers). Technology also has an influence on processes and systems, on society, and on the ways people think, perceive, and define their world.

Specific Learning Outcomes

SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

SLO A4: Recognize that science and technology interact and evolve, often advancing one another.

SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

General Learning Outcome A

Students will...

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

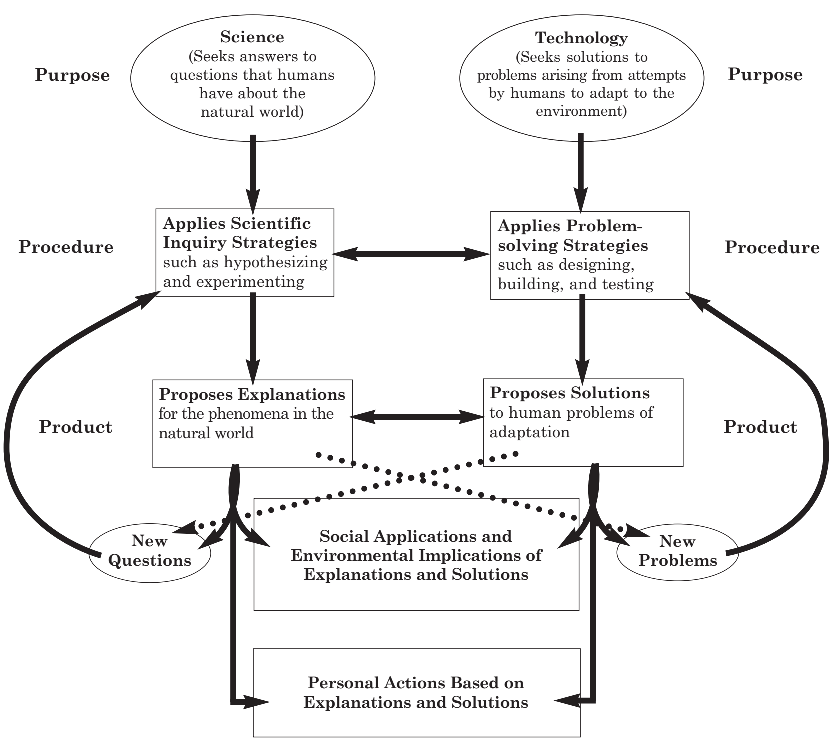
Suggestions for Instruction

Teacher Background

Science and technology are creative human activities with long histories in all cultures of the world. Science is a way of learning about the universe, satisfying curiosity, and producing knowledge about events and phenomena in the natural world. Technology provides effective and efficient ways for humans to accomplish tasks or meet needs. (See illustration below.)

Scientific learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over the evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science argue that there is no set procedure for conducting a scientific investigation.

Science and Technology: Their Nature and Interrelationships



Science and Technology: Their Nature and Interrelationships: Adapted with permission from Rodger W. Bybee, et al., *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction* (Rowley, MA: The NETWORK, Inc., 1989).

Suggestions for Instruction

> Producing science knowledge is an intrinsically collective endeavour. There is no such thing as stand-alone science. Scientists submit models and solutions to the assessment of their peers who judge their logical and experimental soundness by reference to the body of existing knowledge. (Larochelle and Désautels 235)

Scientific theories are being tested, modified, and refined continually as new knowledge and theories supersede existing knowledge bases. Scientific debate, both on new observations and on hypotheses that challenge accepted knowledge, involves many participants with diverse backgrounds.

This highly complex interplay, which has occurred throughout history, is animated by theoretical discussions, experimentation, social, cultural, economic, and political influences, personal biases, and the need for peer recognition and acceptance. Students will realize that while some of our understandings about how the world works are due to revolutionary scientific developments, many of our understandings result from the steady and gradual accumulation of knowledge.

History demonstrates, however, that great advances in scientific thought have completely uprooted certain disciplines, transplanting practitioners and theoreticians alike into an entirely new set of guiding assumptions. Such *scientific revolutions*, as discussed by Thomas S. Kuhn in his influential *The Structure of Scientific Revolutions,* constitute exemplars that can energize the science teaching enterprise, and provide particularly motivating and novel contexts for students.

Technology is concerned mainly with proposing solutions to problems arising from attempts by humans to adapt to the environment. Technology may be regarded as "a tool or machine; a process, system, environment, epistemology, and ethic; the systematic application of knowledge, materials, tools, and skills to extend human capabilities" (Manitoba Education and Training, *Technology As a Foundation Skill Area* 1).

Technology includes much more than the knowledge and skills related to devices such as computers and their applications. It is both a form of knowledge that uses concepts and skills from other disciplines (including science) and the application of this knowledge to meet an identified need or solve a problem using materials, energy, and tools (including computers). Technology also has an impact on processes and systems, on society, and on the ways people think, perceive, and define their world.

Activating

Prior Knowledge Activities

- Students examine the hot coffee example in the Processes for Science Education model. Students create other examples to fit the model.

Processes for Science Education

	Scientific Inquiry	Technological Problem Solving (Design Process)	Decision Making
Purpose:	Satisfying curiosity about events and phenomena in the natural world.	Coping with everyday life, practices, and human needs.	Identifying different views or perspectives based on varying information.
Procedure:	What do we know? What do we want to know?	How can we do it? Will it work?	What are the alternatives or consequences? Which choice is best at this time?
Product:	Knowledge about events and phenomena in the natural world.	An effective and efficient way to accomplish a task or meet a need.	A defensible decision in a particular circumstance.
	Scientific Question	**Technological Problem**	**STSE Issue**
Example:	Why does my coffee cool so quickly? *An Answer:* Heat energy is transferred by conduction, convection, and radiation to the surrounding environment.	How can I keep my coffee hot? *A Solution:* A plastic foam cup will keep liquids warm for a long time. So will an insulated cup.	Should we use plastic foam cups or ceramic mugs for our meeting? *A Decision:* Since we must use disposable cups for the meeting, we will choose a biodegradable type.

Processes for Science Education: Adapted with permission of the Minister of Education, Province of Alberta, Canada, 2005.

- Students use a Compare and Contrast Frame (*SYSTH** 10.24) to make a critical distinction between science and technology.

* *SYSTH* refers to *Senior Years Science Teachers' Handbook* (Manitoba Education and Training).

Suggestions for Instruction

Acquiring

Development of Concepts

- Students use a Compare and Contrast Frame (*SYSTH* 10.20, 10.24) to distinguish between scientific questions and technological problems.

  Examples:

Scientific Question	versus	Technological Problem
• "What is the mechanism responsible for the movement of continents?" • "How does the human body react in a weightless environment?" • "What is a cell?"		• "How could one measure the rate at which two continents are separating?" • "How can we counter the negative effects of weightlessness on a human body?" • "How can a person see organelles inside a cell?"

- Students explain how scientific knowledge evolves as new evidence comes to light and as theories are tested and subsequently restricted, revised, or replaced.

  Examples:

  — Students explain how fossil data contributed to the theory of the evolution of species.

  — Students explain how seismic, fossil, and geological data contributed to the theory of plate tectonics.

Applying

Case Study

- Students explain how scientific knowledge has led to the development of a technological product.

  Examples:

  — kidney dialysis machine

  — laparoscope

  — magnetic resonance imaging (MRI) scanner

  — artificial heart

- Students explain how a scientific or technological milestone revolutionized thinking within a scientific community or research program.

  Examples:

  — How did field theory assist scientists in understanding the motions of celestial bodies or the movement of particles in a magnetic field?

  — How did Pasteur's experiments contribute to an understanding of micro-organisms and disease?

Suggestions for Assessment

- Students use a Concept Organizer Frame such as the Concept Frame or the Concept Overview (*SYSTH* 11.35-11.37) to summarize learning related to the concepts of science and technology. The type of Concept Frame used can be determined by the teacher or by individual students. Some students may prefer to use one frame over another. The frames can be handed in for teacher feedback. As this strategy is intended as a **formative assessment** to check student understanding, a formal, recorded grade for this task is not required.
- A summary of the categories used for each frame is provided below. For more details and blackline masters, refer to *SYSTH* (11.23-11.24, 11.36-11.37).

Concept Frame	Concept Overview
• Concept • Characteristics • Examples • Comparison (What is it like?) • Contrast (What is it unlike?) • Definition • Illustration	• Key word or concept • Figurative representation • Explanation or definition in own words • Facts • Self-generated questions about the concept • Analogy

- *SYSTH* and Appendix 7 offer a variety of assessment strategies that can be linked to specific instructional approaches and the particular needs of students.

General Learning Outcome A

Students will…

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- Brainstorm to generate class discussion on the extent to which science has answered questions about the world and explained natural phenomena, and on further questions that have then arisen.

Acquiring

- Students read and report on a biography or an autobiography of a scientist, looking at the progression and development of scientific understanding.

  Example:
  - *The Double Helix* by James Watson
- Students generate a list of scientific questions and technological problems related to the scientist's work in each of the following categories.

  The scientist
  - has an answer or solution
  - does not have an answer or solution
  - has a limited answer or solution

Applying

- Students identify instances in which science and technology have been limited in their ability to find answers to questions or to the solution of problems.

  Examples:
  - What is the cause(s) of cancer? How is cancer treated? How long will a person who has cancer live?
  - How did life on Earth first develop?
  - What is the inside of the Earth made of?
  - How can we establish a permanent colony in space?
  - How do we explain geological changes on the Earth's surface?
  - What are the causes and treatments of acquired immune deficiency syndrome (AIDS) and severe acute respiratory syndrome (SARS)?

Suggestions for Assessment

- Students critically analyze a piece of scientific writing, such as an article in a scientific journal.
- For a detailed synopsis of how treatment of science writing can be included as an imperative in assessing student's literacy standing, refer to *SYSTH* (Chapter 14).

Teacher Notes

General Learning Outcome A

Students will…

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- Hold a class discussion on societal views of science: *Do different societies have different philosophical views of science? How might a society's philosophy of science and technology be shaped by history and culture?*

  Examples:

  — North American indigenous cultures

  — Asian cultures

  — East Indian cultures

Acquiring

Research

- Students research the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds.
- Students research the development of a particular body of knowledge in science within a society/culture and make a timeline. Different groups may then share and compare their results.

  Examples:

  — knowledge and understanding of the universe

  — knowledge and understanding of disease
- Students research and compare the development of similar research programs in science and technology in different countries. They use a multi-perspective approach, considering scientific, technological, economic, cultural, political, and local environmental factors.

  Examples:

  — space travel

  — medical technologies

  — nuclear power

Applying

Debate

- Students use the debating process to analyze how research programs in science and technology are publicly supported, funded, and influenced by the pressures of priority, merit, and foreseeable influences on the lives of communities.

  Examples:

  — Debate the merits and demerits of funding research in the development of drugs to combat symptoms of AIDS rather than the medical aspects of alcoholism and fetal alcohol syndrome (FAS).

  — Debate the role of pharmaceutical companies in developing new treatments for disease.

  — Debate the relevance of space exploration to life on Earth.

  — Debate the role of homeopathic versus mainstream medical treatments.

  — Debate the importance of the preservation of endangered species of plants and animals to life on Earth.

Suggestions for Assessment

- Students research and analyze the development of science or technology in response to a historical event. Acting as reporters from that time period, they write a news article to illustrate a particular social and historical perspective of a selected topic or scientific advancement.

  Examples:

  — 1944: How did the events of World War II affect the development and use of the atomic bomb?

  — 1632: How did the Copernican view of the universe influence society?
- Students design a new technology or invention and develop a local, national, or global implementation plan for a new idea, taking into account scientific, technological, economic, cultural, political, and environmental factors.

General Learning Outcome A

Students will…

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A4: Recognize that science and technology interact and evolve, often advancing one another.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- In a class discussion, produce a web showing the interconnections between science and technology, using specific examples generated by the students.

Acquiring

Development of Concepts

- Students identify, analyze, and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology.

  Examples:

  — Investigate and describe how seismology has assisted geoscientists in furthering our understanding of the Earth's interior through applications such as seismic tomography.

  — How did the development of the telescope alter society's understanding of the universe and humanity's place within it?

  — How did the refinement of X-ray crystallography techniques lead to the determination of the structure of deoxyribonucleic acid (DNA)?

  — How do the following relate or interact: the development of particle accelerators, the discovery of subatomic particles, and the revision of atomic theory?

- Students analyze natural and technological systems to interpret and explain their structure and dynamics.

  Examples:

  — Analyze the numerous steps involved in refining petroleum to obtain gasoline and a variety of additives for car engines.

  — Examine the production of hydroelectricity.

Applying

- Students describe the functioning of domestic, industrial, or medical technologies by identifying the scientific principles contained in their design.

  Examples:

  — What principles of physics are involved in the design and use of technologies related to computerized axial tomography (CAT scan) or magnetic resonance imaging (MRI)?

  — Describe the development of the aerospace industry and the modern airplane.

Teacher Notes

General Learning Outcome A

Students will...

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- Brainstorm some topics in science and use a concept map to link disciplinary and interdisciplinary processes used to investigate and understand the topics.

  Examples:

  — cloning

  — living in space

  — time travel

  — forensics

Acquiring

Development of Concepts

- Students explain the roles of evidence, theories, and paradigms in the development of scientific knowledge, and discuss how major paradigm shifts can change scientific world views.

  Examples:

  — Explain how the realization that some acidic substances contain no hydrogen in their formula led to a revision of the Arrhenius theoretical definition of acids.

  — Discuss the radical change in thought process that must have accompanied the shifting of views of the Earth as flat and unchanging to round and changing.

  — Compare the evidence and theories of Lamarck and Darwin.

  — Discuss how the theory of plate tectonics explains the global distribution of mammals.

- Students identify and explain the importance of systems of scientific nomenclature and develop personal experience in using them, including communicating the results of a scientific endeavour, using appropriate linguistic modes and conventions.

  Examples:

  — Use geologic conventions from stratigraphy to explain the importance of specifying relative and absolute dating information when describing the location of a particular fossil.

  — Use the appropriate nomenclature to describe the chemical composition of solutions.

  — Use the correct species designation to compare similar organisms.

  — Describe enzyme function.

Applying

- Students identify and model the characteristics of peer review in the development of scientific knowledge.

  Examples:

  — Use rubrics to assess the research papers or laboratory reports of classmates.

  — Write a review of a scientific journal article.

  — Describe how the theory of evolution was refined by the contributions of different scientists.

  — Investigate how the lack of recognition or acceptance by peers resulted in the rejection of many scientific ideas (for example, the ideas of Mendel, Jenner, Galileo).

Suggestions for Teacher Learning Resources

Print Resources

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Teacher Notes

General Learning Outcome B

GLO B

Science, Technology, Society, and the Environment

Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

Overview

Understanding the complex interrelationships among science, technology, society, and the environment (STSE) is an essential component of fostering increased scientific literacy. By studying the historical context, students come to appreciate ways in which cultural and intellectual traditions have influenced the questions and methodologies of science, and how science, in turn, has influenced the wider world of ideas.

Scientific knowledge is necessary, but not sufficient, for understanding the STSE relationships. To understand these relationships fully, it is essential that students consider the values related to STSE.

As a component of achieving scientific literacy, students must also develop an appreciation for the importance of sustainable development. Sustainable development is a decision-making model that considers the needs of both present and future generations, and integrates and balances the impact of economic activities, the environment, and the health and well-being of the community.

Specific Learning Outcomes

SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.

SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.

SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.

SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.

SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

General Learning Outcome B

Students will...

Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

Specific Learning Outcome

SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.

Suggestions for Instruction

Teacher Background

The desire to understand and explain natural phenomena as well as develop solutions to problems to meet a need or fulfill a want is deeply rooted in human nature and has developed along with society. Technology often has a more direct effect on society as it solves practical problems and serves human needs. New problems and needs may then arise. Science enlarges or challenges societal views of the world. A scientific explanation of a phenomenon may lead to a technological development that serves a societal need. Conversely, a societal need or want may result in a technological solution, which then leads to a scientific explanation.

Assessing the impact of a scientific or technological development involves asking questions: What alternate ways are there to achieve the same ends, and how do the alternatives compare to the plan being put forward? Who benefits and who suffers? What are the financial and social costs? Will these change over time and who bears them? What are the risks associated with using (or not using) the new technology? How serious are they? Who is at risk?

As we negotiate our way within our environment, we find an obvious interdependence of STSE, as science and technology work together to solve societal problems and issues. Scientific inquiry is driven by a desire to understand the natural world, and technological inventions result as society demonstrates wants and needs that must be met. Technology, by its nature, has a more direct effect on society than science does because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions and offers explanations for natural phenomena that may or may not directly influence humans (National Research Council, *NSES* 192). By exploring scientific and technological problems and issues, students will develop a rich sense of the relationships linking STSE.

We are seeing the impact of science and technology on our daily lives, in areas ranging from medical and health-related issues to computer and technological advancements. For this reason, science education can no longer be confined to developing basic science concepts and process skills. Students must experience and understand science and technology within the context of environmental quality and societal progress. Teachers can use an STSE approach in providing students with a foundation for making sound STSE decisions that recognize the interrelationships between scientific research, technological solutions, and the complex social and environmental impacts (*SYSTH* 4.3).

An STSE approach to learning science enables students to make connections between what they learn in science classes and what they experience in everyday life. Teachers make these STSE connections within their classrooms in many ways, through explanations, demonstrations, and lab activities. Researching and discussing controversial issues help students think critically, reason, argue logically, and develop opinions supported by evidence. These conflict-resolution and decision-making skills will enable students to become responsible citizens contributing to the future economic, social, and cultural life of Manitoba.

Students will examine the response of society to technological change, as we adopt new technologies or re-examine existing ones. Note that there is a natural connection between SLO B1 and SLO B2.

Suggestions for Instruction

Activating

Entry-Level Knowledge

- Throughout Kindergarten to Grade 8, students develop the design process (technological problem solving).
- Throughout Kindergarten to Senior 2, students develop the process of scientific inquiry.
- Students also acquire key attitudes, an initial awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning. Scientific inquiry and the design process are discussed in more detail in GLO C.

Prior Knowledge Activities

- Teachers may wish to examine students' understanding of the terms *science* and *technology*. How are they related? How are they different?
- Learning activities such as the following allow teachers and students to activate prior knowledge, recognize misconceptions, and relate new information to prior experiences.

  Examples (See Appendix 2):
  - Brainstorming examples of scientific and technological developments
  - Knowledge Chart (*SYSTH* 9.25)
  - KWL (Know-Want to Know-Learned) (*SYSTH* 9.18, 9.24)
  - LINK (List-Inquire-Note-Know) (*SYSTH* 9.18)
  - Listen-Draw-Pair-Share (*SYSTH* 9.15)
  - Rotational Cooperative Graffiti (*SYSTH* 3.15)

Acquiring and Applying

Article Analysis

- Students read and analyze an article describing a recent scientific or technological development using an Article Analysis Frame (*SYSTH* 11.30). They determine whether the development is scientific or technological, and how it will affect development of individuals, societies, and the environment.

Research

- Students research a technological invention, determining the need that was met. They analyze the science involved and describe the relationship between the science and the technology. Students determine what came first—the technology or the science. Students analyze, from various perspectives, the risks and benefits to society and the environment of applying the scientific knowledge or introducing the technology. Finally, students discuss the impact of the development on individuals, societies, and the environment. (See Appendix 4 for research techniques.)

  Examples:
  - changing the bonds formed by using ozone rather than chlorine to disinfect water, thus preventing toxic chlorinated hydrocarbons from forming in treated water supplies
  - alternately powered vehicles (electric, hydrogen cell)
  - technological developments in
    - households (light bulb, plumbing, refrigeration)
    - communication (telegraph, radio, telephone, satellite)
    - transportation (automobile, airplane, rocket, space shuttle)
    - electronics (radio, television, computer)
    - medicine (ultrasound, artificial limbs, electrocardiograms [ECG], MRI, vaccines)
- Alternatively, students may research a scientific development and determine what, if any, technologies have arisen from it.

Case Study

- Students examine a current technological or scientific development and assess its impact on individuals, society, and the environment.

  Examples:
  - cancer treatments
  - development of the automobile
  - organ transplants
  - space flight
  - the computer

Suggestions for Assessment

- Rubric for Assessment of Research Project (see Appendix 9)

General Learning Outcome B

Students will…

Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

Specific Learning Outcome

SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.

Suggestions for Instruction

Teacher Background

Progress in science and invention depends heavily on what else is happening in society. Past history often influences current trends in scientific and technological developments. Individual and societal needs will dictate the type of technology these principles will yield. Students need to understand that science reflects history and is an ongoing, variable enterprise.

Technology, like science, is a creative human enterprise intertwined within the history and cultures of the world. Technology is concerned with proposing solutions to problems arising from human adaptation to the environment. Since there are many possible solutions, there are inevitably many requirements, objectives, and constraints.

Activating

Entry-Level Knowledge

Students have had some exposure to the historical development of scientific knowledge, such as the development of cell theory and microscopes in Grade 8.

Prior Knowledge Activities

- Learning activities such as the following allow teachers and students to activate prior knowledge, recognize misconceptions, and relate new information to prior experiences.

  Examples (see Appendix 2):

  — Brainstorming a list of technological and scientific developments (or use list generated for SLO B1) and connecting development to a particular human need

  — Knowledge Chart

  — KWL

  — LINK

  — Listen-Draw-Pair-Share

  — Rotational Cooperative Graffiti

Acquiring

Research

- Students research the historical and cultural development of a particular science or technology and determine how it may have arisen in response to individual, community, or societal needs and priorities.

  Examples:

  — transportation

  — footwear

  — housing

Applying

Case Study

- Students identify, explore, and analyze a social issue related to science and technology that raises ethical concerns or dilemmas.

  Examples:

  — stem cell research

  — cloning

  — space travel

  — nuclear power

Debate

- Students construct and defend a decision or judgement, and demonstrate that relevant arguments can arise from different perspectives.

  Examples:

  — need for land versus need for hydroelectricity in the construction of a hydroelectric dam

  — quest for knowledge versus ethical and moral dilemma of stem cell research or cloning

  — eradication of smallpox versus need to maintain study samples

  — nuclear power and storage of nuclear wastes

General Learning Outcome B

Students will…

Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

Specific Learning Outcome

SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.

Suggestions for Instruction

Teacher Background

The term *health* is not limited to an individual's mental and physical health but also includes social and environmental health. Both individual and societal choices affect human health. Students will examine the relationships between personal habits and choices and individual and social human health.

Activating

Entry-Level Knowledge

- The physical education/health education curriculum exposes students to a wide variety of health-related issues, including those of personal habits and lifestyle choices. The experience tends to be at a personal level.

Prior Knowledge Activities

- Learning activities such as the following allow teachers and students to activate prior knowledge, recognize misconceptions, and relate new information to prior experiences.

  Examples (see Appendix 2):

  — KWL
  — LINK
  — Listen-Draw-Pair-Share
  — Rotational Cooperative Graffiti

Acquiring

Research

- Students research and present a health-related issue. They examine the relationships between personal habits, lifestyle choices, and human health.

  Examples:

  — smoking
  — nutrition
  — pesticide use
  — fertilizer use

Applying

Role-Playing

- Students may assume the role of different people within a town or a city, such as in a town hall meeting, and respond to an issue affecting community health.

  Examples:

  — construction of a nearby landfill site
  — construction of a high-containment virology lab
  — ban on smoking in public places
  — use of pesticides to control mosquitoes
  — purchasing high-tech medical equipment for a northern community
  — leakage from a local sewage treatment plant
  — fee-for-use waste collection system
  — recycling

Case Study

- Students consider situations in which individual and societal choices affect human and environmental health.

  Examples:

  — Propose guidelines for selecting the most appropriate organ transplant recipient from a number of possible candidates.
  — Respond to a situation where mercury, a by-product of pulp and paper mills, ends up in the water and poisons humans who eat the fish from the water, causing mental illness and blindness.

Suggestions for Instruction

- Address the problems resulting from some hunters using shotgun pellets containing lead, which are eaten by waterfowl that get lead poisoning.
- Develop a personal wellness plan.

Debate

- Students construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives.

  Examples:
  - Should a new housing development be permitted near a high-voltage power line?
  - Should a landfill site be built near your town?
  - Should nuclear waste be disposed of in the Canadian Shield?
  - Should a hog-farming operation be built next door?
  - Should farmers be using genetically modified seed (canola, wheat)?

Teacher Notes

General Learning Outcome B

Students will…

Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

Specific Learning Outcome

SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.

Suggestions for Instruction

Teacher Background

The value of any given technology may vary for different groups of people and at different points in time. Rarely are technology issues simple and one-sided. Relevant facts alone, even when known and available, usually do not settle matters entirely in favour of one side or another. This is because the contending groups may have different values and priorities. They may stand to gain or lose to different degrees, or make very different predictions about what the future consequences of the proposed action will be (AAAS, *Benchmarks for Science Literacy* 56).

Knowledge and personal consideration have strongly influenced the course of technology and continue to do so. It is largely the responsibility for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, sports, and communication that have radically changed how people live. Societies influence what aspects of technologies are developed and how they are used. People control technology (as well as science) and are responsible for its effects (AAAS, *Benchmarks for Science Literacy* 56).

Activating

Entry-Level Knowledge

- Students have been exposed to a variety of career possibilities throughout the Kindergarten to Senior 2 science curriculum.

Prior Knowledge Activity

- Brainstorm a list of science and technology-related careers, interests, and hobbies. Use Concept Maps to link the careers to different fields of science.

Acquiring

Research

- Students research and present a career in a science- or technology-related field. They include educational requirements in addition to a job description.

  Examples:
  - Accountant
  - Aeronautical Engineer
  - Agricultural Economist
  - Astronomer
  - Biochemist
  - Biologist
  - Biosystems Engineer
  - Chemist
  - Computer Technologist
  - Doctor
  - Ecologist
  - Environmental Engineer
  - Environmental Scientist
  - Food Scientist
  - Forensic Scientist
  - Geneticist
  - Geological Engineer
  - Geologist
  - Immunologist
  - Industrial Technologist
  - Lab Technologist
  - Marine Biologist
  - Mathematician
  - Meteorologist
  - Microbiologist
  - Oceanographer
  - Pharmacologist
  - Physicist
  - Virologist
  - Zoologist

Suggestions for Instruction

Applying

Case Studies/Role-Playing

- Students explore science- and technology-related interests, hobbies, and careers through case studies and role-playing scenarios.

  Examples:

  — Act out “A Day in the Life of a __________.”

  — Write an advertisement for a particular science- or technology-related job.

  — Spend a day working with someone in a science- or technology-related field.

  — Organize a science- and technology-related career symposium. This may be simulated, with students acting out the roles of various individuals.

Guest Speaker

- Invite a guest speaker who specializes in a particular science- or technology-related field or who has a particular science- or technology-related interest or hobby.

Suggestions for Assessment

See Appendices 9 for assessment rubrics:

- Rubric for Assessment of Research Project
- Rubric for Assessment of Student Presentation
- Rubric for Assessment of Class Presentations

Teacher Notes

General Learning Outcome B

Students will…

Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

Specific Learning Outcome

SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

Suggestions for Instruction

Teacher Background

In Manitoba, sustainable development is regarded as economic development that is environmentally sustainable. Sustainable development resolves the perceived conflict between economic development and sustaining the natural world. The environment, the economy, and the health and well-being of society are interdependent and interrelated.

Social and economic forces strongly influence which technologies will be developed and used. Success is a result of many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives. When proposals to introduce new technologies or to curtail existing ones are being considered, some key questions arise concerning alternatives, risks, costs, and benefits. What human, financial, material, and energy resources will be needed to build, install, operate, maintain, and replace the new technology, and where will they come from? How will the new technology and its waste products be disposed of and at what costs? What actions will promote a sustainable environment, society, and economy? And, ultimately, how do we determine whether or not we are maintaining a sustainable environment?

Activating

Entry-Level Knowledge

- Sustainable development has been incorporated into the Manitoba science curriculum from Grade 7 to Senior 2.

Prior Knowledge Activities

- Learning activities such as the following allow teachers and students to activate prior knowledge, recognize misconceptions, and relate new information to prior experiences. Teachers should investigate students' understanding of the term *sustainability*.

  Examples (see Appendix 2):
  — Knowledge Chart
  — KWL
  — LINK
  — Listen-Draw-Pair-Share
  — Rotational Cooperative Graffiti

Acquiring

Many of the following learning activities may involve the decision-making model (see SLO C3), as students use information to determine an appropriate course of action.

Research

- Students research economic activities that have an environmental impact. They analyze the economic potential of the action, as well as the environmental consequences.

  Examples:
  — A wood/forestry-products plant in Swan River boosted the local economy and was beneficial to the health and well-being of the local population. How do these benefits balance against the potential effects on the environment and the natural resources in the area?
  — Examine the effects of acid rain on the environment. Propose a course of action.
  — Examine the effects of the introduction of a new species (for example, zebra mussels, lamprey eels, starlings, purple loosestrife), including its impact on the economy, the environment, and human health and well-being.

Suggestions for Instruction

Applying

Debate/Town Hall Meeting

- Students discuss and debate factors and issues related to sustainability.

  Examples:

  — Debate the role of technology in the endangerment of species.

  — Discuss the impact of hunting on the environment, the economy, and the health and well-being of people.

  — Deliberate the role of chemical pesticides, herbicides, and fertilizers on the endangerment or extinction of species.

Case Study

- Students identify and examine, or propose new courses of action on, social issues related to science and technology, taking into account an array of perspectives, including that of sustainability.

  Examples:

  — Examine the process by which octane in gasoline was first achieved by adding tetraethyl lead, an environmental toxin, but is now achieved with unleaded blended gasolines.

  — Investigate the school operating system in terms of the origin, cost, use, and waste for each of water, light, heat, paper, and food.

  — Propose a plan to restore an area to its natural habitat (for instance, wetland, prairie grassland).

  — Examine methods of improving soil quality.

  — Examine the effects of pollution from mining in northern Manitoba on aquatic ecosystems.

  — Develop a personal plan for promoting sustainable development.

Suggestions for Assessment

- Rubric for Assessment Research Project (see Appendix 9)

Teacher Notes

General Learning Outcome C

Scientific and Technological Skills and Attitudes

GLO C

Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.

Overview

General Learning Outcome C (GLO C) will be treated as *three* complementary components:

- Scientific Inquiry
- Design Process (Technological Solutions)
- Science, Technology, Society, and Environment (STSE) Issues and Decision Making

A science education that strives for developing scientific literacy must engage students in answering questions, solving problems, and making decisions. These processes are referred to, for the purposes here, as *scientific inquiry*, the *design process*, and *decision making*. While the skills and attitudes involved in these processes are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

Specific Learning Outcomes

SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.

SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.

SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.

SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.

SLO C5: Work cooperatively with others and value their ideas and contributions.

General Learning Outcome C

Students will…

Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.

Specific Learning Outcomes

SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.

SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.

SLO C5: Work cooperatively with others and value their ideas and contributions.

Suggestions for Instruction

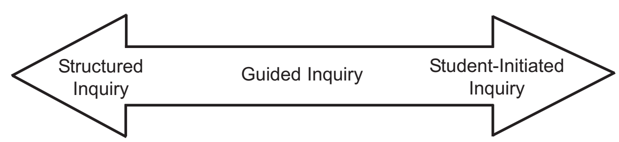
Scientific Inquiry

Scientific inquiry is an effective means of constructing knowledge and teaching the processes of science. Embedding teaching strategies within an overall inquiry-based pedagogy can enhance student performance and attitudes about science. Students become actively engaged in the learning process when given opportunities to hypothesize and investigate. Students are personally able to construct their own knowledge by posing questions, planning investigations, conducting their own experiments, and analyzing and communicating their findings. Also, students have opportunities to progress from concrete to abstract ideas, rethink their hypotheses, and retry experiments and problems (Jarrett; NRC, *National Science Education Standards*).

Inquiry must be developed in context and with connections to meaningful content. Building on relevant and accurate knowledge, teachers guide students in the logical development and integration of ideas. Scientific inquiry will allow students to gain skill in the practice of the methodology of science, including the development of hypotheses, theories, metaphors, laws, empirical and mathematical analysis, experimental and analytical design, observation, objectivity and perception, peer review, criticism, and consensus building. Scientific inquiry improves critical-thinking skills, including those related to deduction, induction, intuition, causality, association, and probability, as students investigate phenomena and construct meaning from data and observations.

Inquiry-based teaching often occurs on a continuum, with strategies and activities appropriate for a particular situation. At one end of the continuum is *structured inquiry*, where students engage in highly structured hands-on activities following precise instructions. In the middle of the continuum is *guided inquiry*, where students may assume responsibility for determining the procedure for an investigation, but the teacher chooses the question to be investigated. At the far end of the continuum is *student-initiated inquiry*, in which students generate their own questions and investigations. Student-initiated inquiry provides opportunities for students to exemplify thinking and behaving in scientific ways to solve personally and socially important problems. Students focus on all aspects of inquiry, designing and exploring an investigation in accordance with sound science practices.

A Proposed Continuum for Inquiry-Based Teaching

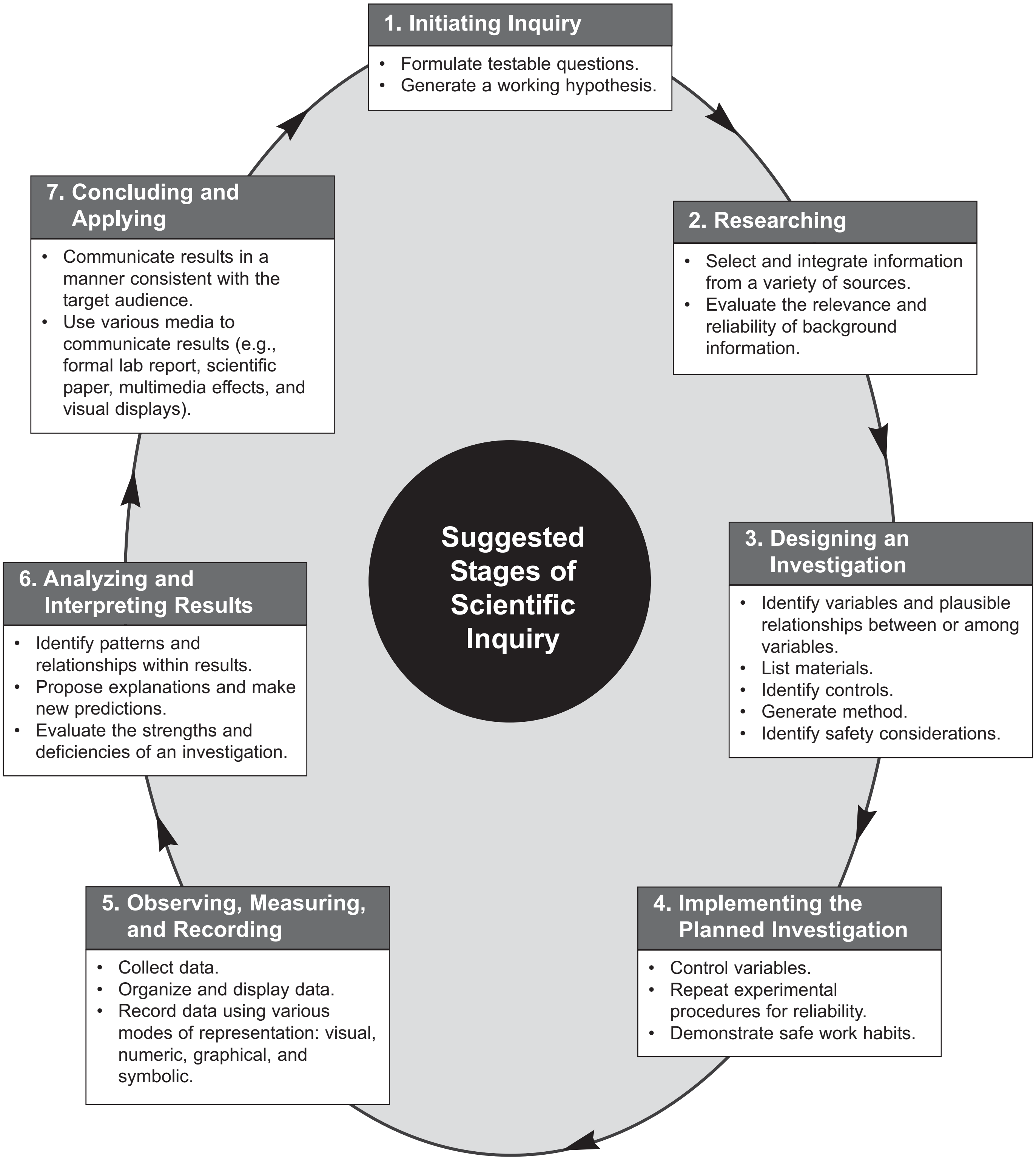


For students to develop into critical thinkers, they need to experience the freedom and responsibility of directing and focusing their own inquiries. (Strategies to move from pre-designed to student-designed laboratories are outlined in *SYSTH* 4.10-4.13.)

The Stages of Scientific Inquiry are illustrated on the following page.

Suggestions for Instruction

Stages of Scientific Inquiry



Suggestions for Instruction

Activating

Entry-Level Knowledge

- Throughout Kindergarten to Senior 2, students develop the scientific inquiry process.
- Senior 3 students have already developed scientific inquiry skills to allow them to propose testable questions and develop a hypothesis/prediction. Students locate, evaluate, and summarize relevant information from a variety of sources. They plan and carry out procedures, including the identification and treatment of materials, variables, controls, methods, and safety considerations. Students work cooperatively to collect, organize, and display data. They interpret patterns and explain relationships, forming conclusions. Students also develop key attitudes, an initial awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning.

Prior Knowledge Activities

- Learning activities and strategies such as the following allow teachers and students to activate prior knowledge, recognize misconceptions, and relate new information to prior experiences. In scientific inquiry, students must link personal science theories with generally accepted concepts of the science community. Discussion will allow an evaluation of this understanding, which may lead to the formation of questions and hypotheses.

  Examples of Strategies (See Appendix 2):

  Activities to activate prior knowledge include

  — Anticipation Guide
  — Discrepant Event
  — Drawing/Illustration of Concept
  — Knowledge Chart
  — KWL
  — LINK
  — Listen-Draw-Pair-Share
  — Rotational Cooperative Graffiti

The Stages of Scientific Inquiry: A Suggested Continuum

The stages of scientific inquiry (as illustrated diagrammatically on the previous page) are *general guidelines only*. They may not all be used as components in every scientific inquiry, nor do they occur in the same order in every situation. It is important for students to realize, through experiencing diversity, that no one specifiable "scientific method" is appropriate for investigating the natural world in all situations. It is a lingering, pervasive myth that science proceeds toward uncovering the "truths" of nature through its unique processes of inquiry, and that it is eminently successful at doing so.

1. **Initiating Inquiry**

   The general method of scientific inquiry often begins with a question, which is raised while observing relationships among natural phenomena. If there is no known answer to the question posed, then one or more plausible hypotheses or explanations can be tested by means of a scientific experiment to answer the question. The success of a scientific law, theory, or model is determined by its accuracy in predicting natural phenomena. As experiments are repeated and redesigned, scientists continually refine the existing prevailing scientific theories that govern their interpretation of data and observation, and construct refined models to match experimental results and to make better predictions about the behaviour of natural phenomena. For instance, if a theory cannot successfully make predictions or generate novel facts about phenomena, then holding on to it must be questioned.

   The inquiry process is especially relevant to students when they formulate their own questions. A good testable question will enhance students' ability to make predictions (e.g., a *working hypothesis*), create a plan, conduct fair tests, and make relevant observations and conclusions. Teachers may support this process with prompting and probing questions, helping students to define, focus, and delimit questions and problems to facilitate practical investigations.

Suggestions for Instruction

- **Formulate Testable Questions**

  A good, but simplified, testable question will often take the form of "How does ____ affect ____?" It will focus testing on only one factor (*Example*: "What is the effect of sunlight on the growth of plants?" instead of "What affects the growth of plants?").

  Example of a Testable Question:

  — *What is the effect of the application of heat on the viscosity of a fluid?*

  The above question includes the cause (the application of heat) and the effect (viscosity of a fluid). These two portions of the testable question are called variables. *Variables* are factors that can affect an event or process in some way. The *independent variable* is the **one** variable we choose to change. The *dependent variable* changes as a result of, or in response to, the change in the independent variable.

  Sometimes placing the variables in the following manner helps to identify each portion:

  ____________ depends on ______________
  dependent variable **independent variable**

  If we were to apply this approach to the testable question above, we might say:

  The viscosity of a fluid depends on the application of heat.
  dependent variable **independent variable**

  Example of Strategy:

  — Concept Relationship Frame—to examine associations between variables (*SYSTH* 11.20, 11.35)

- **Generate a Working Hypothesis**

  A *hypothesis* is a suggested answer of how one variable affects the other. The hypothesis should describe the relationship between the independent and dependent variables. Often it follows an *if-then* pattern:

  If the amount of heat added increases (**independent variable**), then the viscosity will decrease (**dependent variable**).

  Examples of Strategies (See Appendices 2 and 6):

  Activities to generate testable questions and generate a working hypothesis include

  — Brainstorming—Class/Group Discussion
  — Discrepant Event
  — KWL
  — Listen-Think-Pair-Share
  — Research and Debate
  — Rotational Cooperative Graffiti
  — Roundtable

2. **Researching**

   The research portion of scientific inquiry may take place at various stages during scientific inquiry.

   - **Select and Integrate Information from a Variety of Sources**

     It is important that students select and integrate information from a variety of sources, compiling and organizing information using appropriate formats and treatments.

   - **Evaluate Relevance and Reliability of Background Information**

     Students identify and apply criteria for evaluating evidence and sources of information, examining the reliability, bias, and usefulness of information gathered. Students then summarize and record the information in a variety of forms, including paraphrasing, quoting relevant facts and opinions, and referencing.

     Examples of Sources:

     — **Print**
       – texts
       – newspaper articles
       – journals
       – magazines

     — **Electronic**
       – Internet
       – videos
       – CD-ROMs
       – television

     — **Community**
       – resource people

Suggestions for Instruction

Examples of Strategies (see Appendices 4 and 5):
- — Article Analysis Frames
- — Case Studies
- — Concept Mapping
- — Fact-Based and Issue-Based Article Analysis
- — Literature-Based Research Projects
- — Reading Scientific Information
- — WebQuest

3. **Designing an Investigation**

   A written plan for scientific inquiry could include the apparatus, materials, safety considerations, and steps to follow. It identifies and controls the major variables.

   - **Identify Variables and Plausible Relationships between or among Variables**
     The key to designing successful experiments is the identification of all variables relevant to both the observed phenomenon and the question posed. Ideally, a scientific experiment is one in which all experimental variables except one are controlled by the experimenter. As the experiment runs, only one variable is free to change, while all others are held constant.
   - **List Materials**
     Students select the appropriate instruments for data collection. Manipulating common tools and lab equipment allows students to create simulations and working models to test their ideas. Students should be able to explain why materials were chosen.

     Example of Strategy:
     — Three-Point Approach—to describe and illustrate materials (*SYSTH* 10.9, 10.22)
   - **Identify Controls**
     Students identify the variables that are controlled and explain why it is important to have those controls.
   - **Generate a Method**
     Upon generating a procedure, students summarize and discuss the method, explain why this is the best procedure, and define terms used.
   - **Identify Safety Considerations**
     Students recognize and identify safety considerations.

     Example of Safety Resource:
     — *Science Safety: A Kindergarten to Senior 4 Resource Manual for Teachers, Schools, and School Divisions* (Manitoba Education and Training)

4. **Implementing the Planned Investigation**

   Teachers may illustrate or demonstrate processes and encourage students to follow their procedures with open minds. Students should maintain an awareness of planned procedures and those followed, noting any changes and why they occurred.

   - **Control Variables**
     Students identify the variable being manipulated and monitor the process to ensure that other variables remain constant.
   - **Repeat Experimental Procedures for Reliability**
     To increase accuracy and reliability, students ensure that they perform an adequate number of trials to make data collection meaningful and replicable.
   - **Demonstrate Safe Work Habits**
     During the course of the procedure, students demonstrate safe work habits.

5. **Observing, Measuring, and Recording**

   Students select and use appropriate methods and tools for collecting data or information. They estimate and measure accurately using the SI system and other standard units. Students should be able to read instruments accurately and explain how measurements and calculations were made.

   - **Collect Data**
     The teacher may model the process of "observing" during data collection. Students concentrate on technique and precision.

     Model observation by asking questions:
     — What does each mark on the...represent?
     — Did you estimate according to a procedure we have recognized as effective...?
     — Would you get the same measurement if...?

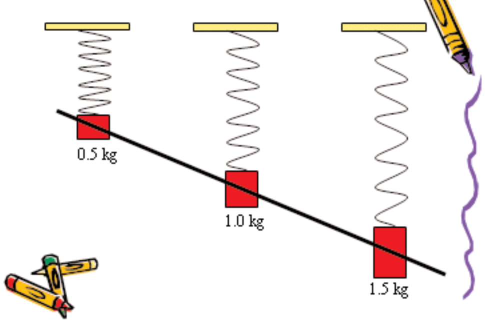
Suggestions for Instruction

- **Organize and Display Data**
  Students determine what is to be measured before experimentation, and construct a data table accordingly. Teachers suggest and model logical and meaningful ways of organizing and displaying data. Students transform raw data to reveal patterns, reveal relationships between variables, or clarify results. They record, organize, and display observations and data using an appropriate format, including point-form notes, diagrams, sentences, charts, lists, spreadsheets, graphs, and frequency tallies.
- **Report Data Using Various Modes of Representation**
  Data may be represented in various ways within an investigation, using visual, numerical, graphical, and symbolic modes.
  Examples of Modes of Representation:

  — **Visual Representation**
  - Represent visible relationships among variables (see graphic below).
  - Describe how the experimental run unfolds.

Visual Representation

If we add more mass the spring stretches more.



— **Numeric Representation**
- Use rounding and significant figures.
- Order data.
- Use error analysis.
- Create charts and/or tables.
- Identify patterns in the raw data.

Numeric Representation

Typically, a visual representation is not enough to determine a relationship accurately. Therefore, we quantify the relationship by making measurements.

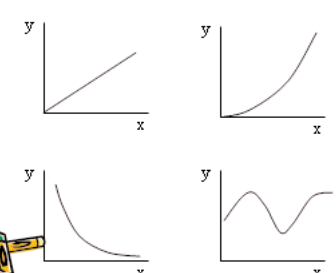
F (N)	X (cm)
1.0	0.2
2.0	0.4
3.0	0.6
4.0	0.8

Students look for patterns emerging in the data (for instance, if force doubles from 1.0 to 2.0, what happens to spring stretch?).

— **Graphical Representation**
- Use appropriate graph type(s) (e.g., Which graph below matches our spring stretch data?)
- Use correct scaling on axes.
- Tell "the story" from this "picture of the numbers."
- Identify a line of best-fit (e.g., linear regression).
- Interpolate and extrapolate.

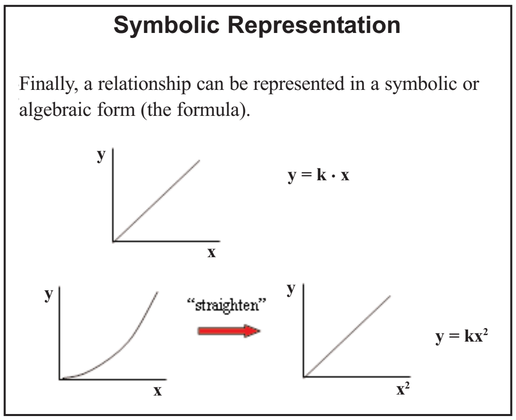
Graphical Representation

A graph is a "picture" of the numbers.

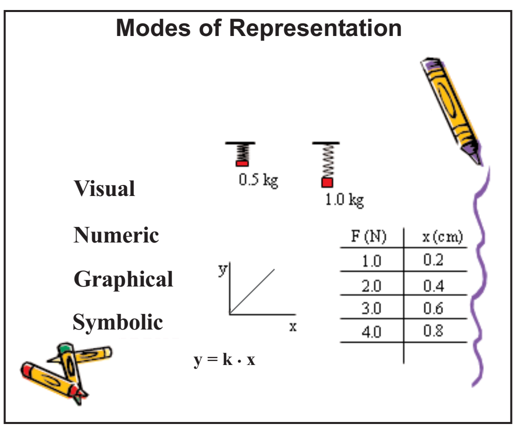


Suggestions for Instruction

— **Symbolic Representation**
- – Determine slope from a linear relationship.
- – Connect slope at a particular point on a non-linear curve to an “instantaneous” rate of change.
- – Derive model equations for data.
- – “Straighten” the curve to determine non-linear relationships.



Summing up the Four Modes of Representation:



6. **Analyzing and Interpreting Results**

   Students analyze data and apply appropriate mathematical and conceptual models to assess possible interpretations and explanations. They select and apply appropriate visual, numeric, graphical, symbolic, and linguistic modes of representation to communicate ideas, plans, and inquiry results effectively.

   - **Identify Patterns and Relationships within Results**

     Students should interpret patterns and trends in data, and infer and explain relationships using language such as increasing, decreasing, linear, curvilinear, repeating, unchanging, and extrapolations. Encourage students to talk about the patterns in data, looking at general and specific patterns.

     Model the language for talking about patterns:

     — What do these numbers in the data chart tell us about what occurred?

     — For every change of...in the *dependent* variable, the *independent* variable changes....

   - **Propose Explanations and Make New Predictions**

     Students propose explanations and make predictions from their data, identifying limits, exceptions, or alternate interpretations of the data. Guide students back to their background information to compare their thinking with their findings.

     Students identify and suggest explanations for discrepancies in data, including sources of error, such as difficulty in control, insufficient data, inaccurate measurements, equipment limitations, and time constraints.

   - **Evaluate Strengths and Deficiencies of Investigation**

     Students evaluate the original plan for investigation and suggest improvements, identifying strengths and weaknesses of data collection methods and design flaws.

Suggestions for Instruction

7. **Concluding and Applying**

   At this stage, students reflect on prior knowledge and experience to develop new understandings. They develop a conclusion that explains the results of the investigation, supporting or rejecting the hypothesis or prediction. Teachers may use divergent and redirecting questioning techniques to help students develop their conclusions. If the data confirms the hypothesis, students state the supporting evidence. They consider cause and effect relationships and make connections to accepted scientific information. Students may also consider alternative explanations, repeat the experiment, and pose questions and hypotheses for further study.

   - **Communicate Results**

     Conclusion(s) should explain the relationship between the independent variable and the dependent variable if that is the design of the scientific inquiry.

     Example of Conclusion for Experiment:

     Here is an example of a conclusion on an experiment that involved *sunlight* and *plant growth:*

     > *In our experiment, all variables, other than the amount of sunlight, were kept constant. The geranium plants that received additional sunlight did grow more than the plants that were given limited amounts of sunlight. In the 32 days that we ran the experiment, the plants that received an additional 10 hours of sunlight a day grew an average of 3 cm, while the plants that received only limited sunlight grew an average of 1 cm. Our results, therefore, support our hypothesis.*

     In addition to revisiting the hypothesis, the conclusion should include the sources of error in the experiment. These would be factors that may impede the accuracy of the data. In the reflections on the process component of the conclusion, the teacher may want to suggest ways to improve the experiment.

     An additional component to the conclusion deals with what implications or applications the experiment or concept has for everyday living.

   - **Use Various Media to Communicate Results**

     Students may present their findings in various ways, depending on the purpose or intention of the inquiry and the results. Inquiry-based results are commonly communicated in the form of a written lab report, a scientific paper, or a presentation. Teachers may structure and facilitate discussions based on a shared understanding of the rules of scientific discourse, such as justifying understandings, basing arguments on data, and critically assessing the explanations of peers. Encourage students to offer their own ideas, to make comments, to debate the validity of explanations and solutions, and to take part in the decision making.

     Examples of Media to Communicate Results:

     — **Written Lab Report**

     Students learn to summarize and analyze laboratory experiences. They may use the following:

     – Laboratory Report Outline (*SYSTH* 11.28-11.29)
     – Formal Lab Report Outline (*SYSTH* 11.38-11.39)

     Students may initially find that generating an entire report is overwhelming, and may get caught up in the *standard format* rather than the actual science that matters. Teachers may choose to spend time developing the parts of the report separately, such as stating the purpose or presenting the data.

     — **Scientific Paper**

     A scientific paper can be a means to identify and attempt to resolve a scientific problem, outline the results of recent research, or examine (to validate) how tests have been conducted to explore key predictions from scientific theory. Students may consider using a scientific writing format that has been agreed upon in consultation with the teacher.

Suggestions for Instruction

- **Presentation**
  Scientific inquiry results may be delivered in the form of presentations:
  - multimedia presentation (e.g., PowerPoint)
  - oral presentation
- **Visual Displays**
  Information gathered through the process of scientific inquiry may be communicated through visual displays:
  - tables
  - graphs
  - labelled diagrams
  - charts
  - posters
  - models
  - Concept Maps
  - cartoons
- **Journal Writing**
  Students may reflect and respond to a question using a variety of formats, such as Concept Maps.

Suggestions for Assessment

Assessment techniques such as the following could be applied to the scientific inquiry process:

- **Rubrics/Checklists**
  - Lab Report Assessment (see Appendix 9)
  - Observation Checklist: Scientific Inquiry—Conducting a Fair Test (see Appendix 9)
- **Performance Assessment**
  Assessment strategies may include the following:
  - Demonstrate a lab technique (e.g., lighting a Bunsen burner, using a balance, focusing a microscope).
  - Demonstrate a safety procedure.
  - Interpret Workplace Hazardous Materials Information System (WHMIS) labels.
  - Identify an unknown.

Note:

Develop assessment criteria with students. The criteria should include both content and presentation components and may be similar, regardless of which presentation form students choose. Assign a point value to each criterion, or use a simple rating scale (e.g., excellent, good, fair, poor) for each.

General Learning Outcome C	Specific Learning Outcomes	
Students will… Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.	**SLO C2:**	Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.
	SLO C4:	Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.
	SLO C5:	Work cooperatively with others and value their ideas and contributions.

Suggestions for Instruction

Design Process (Technological Solutions)

Problem solving has been defined in many ways. One definition describes a problem as a need that must be met. This need could include, among other things, the need to understand the forces of nature (science), to alter the environment (technology), or to use scientific knowledge to alter the environment (engineering). *Technological problem solving* can be divided into three categories: design, troubleshooting, and technology assessment (impact evaluation).

Technological problem solving is a universal response to human needs and wants. Needs are basic, such as food, shelter, and other things considered essential to survival. Wants are much broader, and include the full range of things people would like to have. Often, a want is perceived by an individual only after an opportunity to meet it is presented. This is frequently the case in our consumer society.

Technological activity involves the application and consumption of resources, including information, knowledge, capital (money), time, raw and synthetic materials, tools, machines, and people. The best possible solutions are identified based on a careful consideration of the problem and available resources. After appropriate evaluation, a solution is adopted. The solution always has outcomes—some known, some unknown, some positive, some negative. Invariably, technological solutions lead to more needs, wants, problems, and opportunities, and the cycle continues.

Technological problem solving often involves the following steps: identifying the problem, postulating possible solutions, testing the best solution, and determining whether the problem is solved. Knowledge and understanding are necessary to solve complex problems and to allow students to transfer learning to other situations.

Design projects are structured around real-world objects. Students may bring some of their knowledge of the world to their design. In addition to deciding what a design will look like, students identify what they want the design to do and how they will evaluate whether it meets that goal. Design projects provide a context for scientific communication. In an open-ended design context, knowledge acquired by one may be applied by all, in very different ways.

Since testing designs produces data that may be used as evidence, students have opportunities to present and critique scientific arguments that explain the performance of different designs.

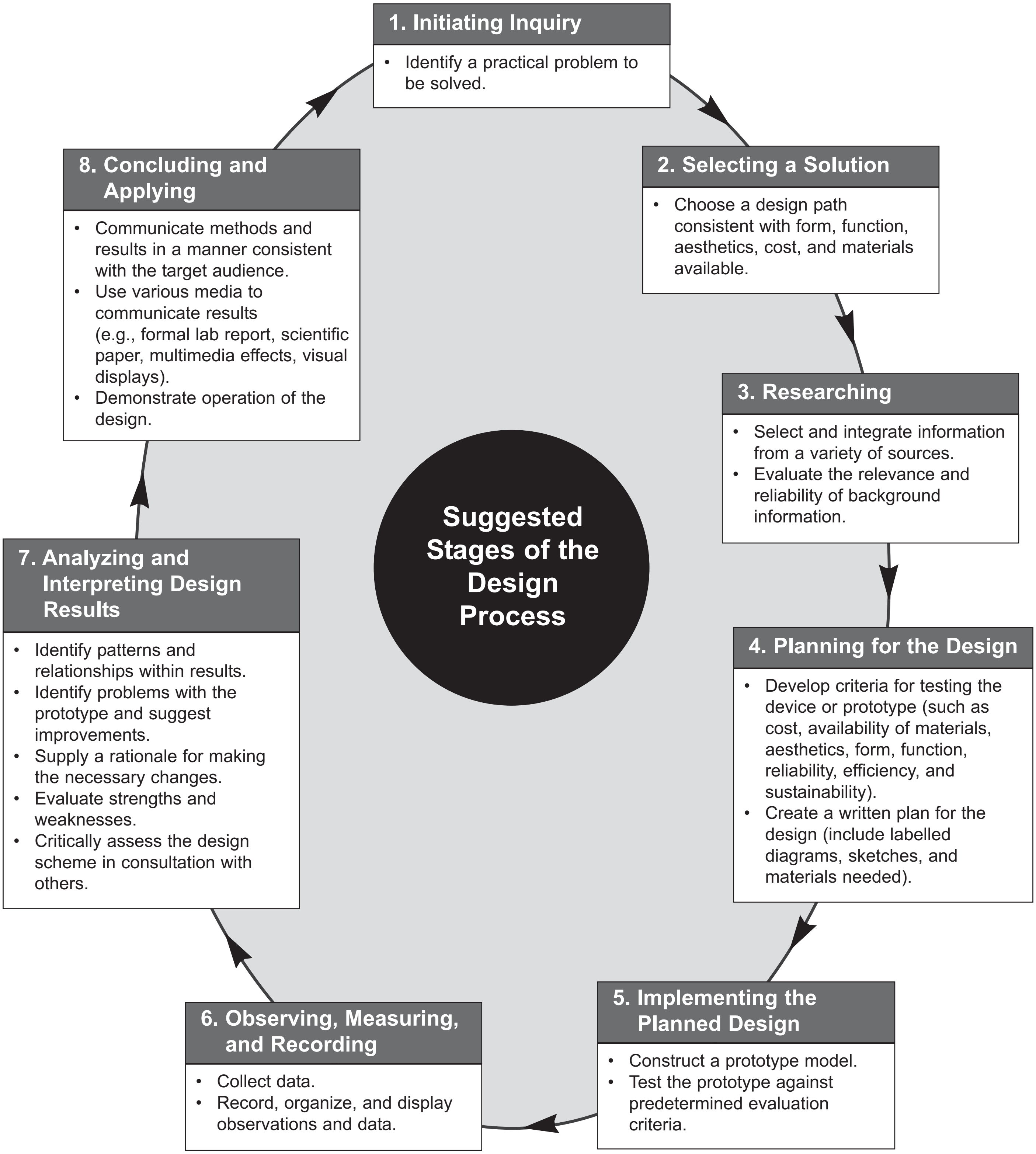
Students propose, build, test, evaluate, and redesign their designs. Design challenges may be posed to students, or students may have the responsibility of deciding for themselves what object they will design for what purpose. Guiding questions, posed by written activities, the teacher, and structured design journals, emphasize explanation and prompt students to focus their experimentation on explanation as well as performance. Initial activities that lead up to the design task provide students with an understanding of scientific principles they can apply to their designs, and also model the process of pursuing answers to scientific questions.

Providing opportunity for redesign has several benefits. First, it gives students a chance to apply what they learned from building and testing earlier designs. Testing may also uncover new constraints or important properties that lead students to revise their experiments and redefine the questions, methods, and means of testing they have been pursuing. When teaching design, teachers need to develop a strategy that not only tolerates but also rewards alternative solutions.

The diagram that follows illustrates the suggested Stages of the Design Process: Constructing a Prototype.

Suggestions for Instruction

Stages of the Design Process: Constructing a Prototype



Suggestions for Instruction

Overall Expectations

Students could achieve the identified learning outcomes through learning experiences such as the following:

- Construct a prototype and test the device.
- Observe, measure, record, organize, and display data using appropriate formats such as labelled diagrams, tables, and graphs.
- Analyze data improvements.
- Select and apply appropriate visual, numeric, graphical, symbolic, and linguistic modes of representation to communicate ideas, plans, and inquiry results effectively.
- Communicate questions, ideas, and intentions, as well as receive, interpret, understand, support or refute, and respond to the ideas of others with models. (For example: *Participate in a group activity where the positions of Earth's continents at various times in the past are shown with three-dimensional models of Earth. Modelling clay could be used as the continental pieces attached to a globe. Can a good "fit" of the continents be achieved on an Earth of modern radius, or are there unexplainable gaps? How would two different theories—plate tectonics or the expansion of the Earth—respond to the problems that arise when we perform such "puzzle fits" of the continents?*)
- Select and integrate information from various print, electronic, and multimedia sources, and compile and organize information using appropriate formats and data treatments.
- Identify and apply criteria for evaluating evidence and sources of information, including the presence of bias.
- Work collaboratively in planning and carrying out investigations, and in generating and evaluating ideas.
- Listen, evaluate, and respond to the individual or group work of others, including an assessment of the credibility, accuracy, and potential biases of information presented.

Activating

Entry-Level Knowledge

- Throughout Kindergarten to Grade 8, students develop the design process. They construct prototypes to solve practical problems and analyze them according to criteria such as cost, efficiency, and environmental considerations.
- In the Senior Years, students continue this continuum at a greater level of expectation for sophistication. Students continue to apply their problem-solving skills in the evaluation of consumer products to determine the best product for a particular purpose. They are able to identify practical problems to solve. Students locate, evaluate, and summarize relevant information from a variety of sources, develop evaluation criteria, and create a plan to solve a problem. Students construct and test a prototype using observational, measurement, and recording skills. They work cooperatively to collect, organize, and display data. Students evaluate the prototype and identify a solution to the problem. In addition, students develop key attitudes, an initial awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning.

Prior Knowledge Activities

- Learning activities and strategies such as the following allow teachers and students to activate prior knowledge, recognize misconceptions, and relate new information to prior experiences.

  Examples of Strategies (See Appendices 2 and 3):

  — Anticipation Guide
  — Discrepant Event
  — Drawing
  — Knowledge Chart
  — KWL
  — LINK
  — Listen-Draw-Pair-Share
  — Rotational Cooperative Graffiti
  — Sort and Predict

Suggestions for Instruction

Vocabulary-Building Activities

- Learning activities and strategies such as the following allow teachers to assist students in accessing the vocabulary they already know or prepare them to learn vocabulary so that they will better understand new material.

  Examples of Strategies (See Appendix 3):

  — Sort and Predict

  — Three-Point Approach

  — Webs and Clusters

The Stages of the Design Process

1. **Initiating Inquiry**
   - **Identify a Practical Problem to Be Solved**
     Students carefully analyze the design problem and break it into the smallest systems and subsystems possible. They clarify the problem to determine exactly what they have been asked to create or design. Students devise and implement a strategy that employs a variety of sources for identifying and investigating real-life communication problems and opportunities. They identify and clearly state needs, problems, and opportunities related to human-human, human-machine, and machine-machine communications. Finally, they develop a design brief that clarifies and states the communications problem to be resolved.

     For example, a practical problem for solution such as "*use the design process to construct a prototype device that determines time of day from the sun's shadow"* could be presented in the following manner:

     Design and construct a prototype device that determines time of day from the sun's shadow for a group of wilderness athletes on an adventure race. The athletes will not carry any watches or clocks, and need to arrive at a particular destination for pick-up at a specified time.

     Students, ideally, should be involved in the problem identification. The problem should be framed within a context. This might involve a real-world problem or a scenario linked to another discipline, such as social studies or literature selection. It is critical that the design challenge presented to students is problem focused, as opposed to product focused. For example, "construct a boat" is a product-focused challenge, while "construct a floating device to transport a load of three blocks across a span of water one metre wide" is a problem-focused challenge. The problem must also be open-ended to encourage optimum solutions.

     Examples of Strategies (See Appendices 2 and 6):

     — Brainstorming

     — Class or Group Discussion

     — Listen-Think-Pair-Share

     — Rotational Cooperative Graffiti

     — Roundtable

2. **Selecting a Solution**
   - **Choose a Design Path**
     Students create as many solutions to the design problem as possible before attempting to implement any of them. They choose a design path consistent with form, function, aesthetics, cost, materials, and so on. Design teams ask questions such as the following.

     Examples of Questions:

     — Are there other ways to solve this problem or use these materials?

     — Can I borrow, adapt, or extend existing solutions or technologies?

     — Can I add a new element or twist that might lead to a solution?

     — Can I add more to the problem in an effort to find a solution?

     — Can I remove parts of the problem in an effort to solve it?

     — Can I incorporate substitutes or use other materials or technologies?

Suggestions for Instruction

- — Can I rearrange the elements of the problem to find the solution?
- — Can I do the opposite of what I am currently thinking?
- — Can I combine elements or technologies to solve the problem?
- — Can I examine the range of ideas explored and the strategies used in the design brief as a means of improving the solution and presenting a coherent plan for developing the solution?
- — Can I develop multiple options for a solution and identify the most appropriate solution, considering conservation of resources, suitability of the solution, outcomes of the solution, and the technical activity required to produce it?

3. **Researching**

The research portion of the design process may take place at various stages.

- **Select and Integrate Information from a Variety of Sources**
  It is important that students select and integrate information from a variety of sources, compiling and organizing information using appropriate formats and treatments.
- **Evaluate Relevance and Reliability of Background Information**
  Students identify and apply criteria for evaluating evidence and sources of information, examining the reliability, bias, and usefulness of information gathered. They then summarize and record the information in a variety of forms, including paraphrasing, quoting relevant facts and opinions, and referencing. Students may incorporate knowledge, concepts, and problem-solving strategies from other disciplines in solving technological problems.

Examples of Sources:

- — **Print**
  - – texts
  - – newspapers
  - – journals
  - – magazines
- — **Electronic**
  - – Internet
  - – videos
  - – CD-ROM
  - – television
- — **Community**
  - – resource people

Examples of Strategies (see Appendices 4 and 5):

- — Article Analysis Frames
- — Case Studies
- — Concept Mapping
- — Fact-Based and Issue-Based Article Analysis
- — Literature-Based Research Projects
- — Reading Scientific Information
- — WebQuest

4. **Planning for the Design**

- **Develop Criteria for Testing the Device or Prototype**
  Students develop and apply appropriate objective and subjective criteria for evaluating a need. Design specifications and design studies may take into account aesthetics, function, quality construction, and the user. Criteria must be specific enough to limit the scope of impractical solutions and ensure success, but also open-ended enough to allow originality and creativity. It is also important that the criteria are *testable*.

Suggestions for Instruction

Criteria should be generated with student input. They should also be framed in the context of the science learning within the cluster of targeted learning outcomes. The teacher may need to specify certain criteria related to the learning outcomes and available materials, whereas students will often identify "real-life" types of criteria. In developing criteria, students should address function, cost, and aesthetics.

To ensure that each of the specified criteria is testable, students need to provide descriptors. These might include the following:

— **Aesthetics:** For some prototype solutions, aesthetics are an important factor. The criterion of being "visually appealing" can be included, but further descriptors (e.g., colour, scale, finishing) facilitate evaluation.

— **Cost:** The inclusion of cost heightens student awareness of issues of product production and cost-effectiveness. This criterion can be included by assigning a monetary value to materials or processes involved in the construction of the prototype.

— **Form, Function, Reliability, and Efficiency:** Criteria addressing the form, function, reliability, and/or efficiency of the prototype must be clearly specified to ensure consistency in testing. These criteria often have a strong overlap with the scientific inquiry process, as the concept of a "repeatable, fair test" is applied.

— **Sustainability:** Criteria that include the use of recycled materials or environmental considerations focus student awareness on sustainability and the potential environmental impacts of design solutions on the environment. This links with the Science, Technology, Society, and Environment (STSE) component of the Senior 3 Current Topics in the Sciences curriculum.

- **Create a Written Plan for the Design**
  At this stage, the group of students generates several ideas and selects the best possible solution to the proposed problem. The teacher assists in activating students' creative thinking skills of fluency, flexibility, elaboration, and originality. This will encourage optimum solutions to the problem. The group then identifies appropriate materials, safety considerations, and a logical sequence of steps to follow. Students record their plan, including labelled diagrams of the top and side views of the prototype, and three-dimensional sketches where possible. It is important that students are aware of the value of the labelled sketch. It provides a visualization of the prototype to guide the construction and serves as a draft blueprint. The constructed prototype can be (and likely will be) altered from the initial sketch, and an explanation of the need for changes is an important aspect of student learning. In creating a plan for the design and construction of the prototype, it is useful to have students include a plan/instrument to test the prototype according to the criteria identified and following a fair-test approach.

  Students create a written plan, in which they

  — specify a timeline

  — assign tasks

  — list materials (students explore a broad range of tools, materials, and processes)

  — identify safety precautions

  — draw diagrams (showing design changes)

5. **Implementing the Planned Design**
   - **Construct a Prototype Model**
     Constructing the designed prototype gives students opportunities to apply their understanding of the properties of materials and their uses. It encourages students to identify information needs and to access the required information through research. In addition, it enables students to apply the science knowledge and skills they have acquired through that particular science cluster in a practical context.

Suggestions for Instruction

For example, a design problem associated with a specific problem such as "*use the design process to construct a structure that will withstand the application of an external force*" requires students to apply the following knowledge and skills:

- — Identify internal and external forces and the stress they apply to structures.
- — Identify the centre of gravity and its effect on stability.
- — Determine the efficiency of the structure as it relates to mass, investigating the effect of a force in terms of its magnitude, direction, plane, and point of application.
- — Determine methods to increase the strength and stability of a structure.

Students require experience with key concepts and skills prior to the design project. The construction stage may involve the generation and revision of ideas and the identification of the need for further research. This could result in a solution that differs from the original plan.

- **Test the Prototype against Predetermined Criteria**
  Students test the prototype against the predetermined evaluation criteria. They select and use appropriate tools and instruments to conduct a fair and consistent test. Students will use accurate estimates and measurements and record their observations and results. Students often need to be reminded that their prototype must address *all* the criteria identified.

6. **Observing, Measuring, and Recording**
   Students select and use appropriate methods and tools for collecting data or information. They estimate and measure accurately using the SI system and other standard units. Students should be able to read instruments accurately and explain how measurements and calculations were made.

- **Collect Data**
  Teachers may model the process of "observing" during data collection. Students concentrate on technique and precision when making their design operational.
  Model observation by asking questions:
  - — What does each mark on this object represent?
  - — Did you estimate according to a procedure we have recognized as effective...?
  - — Would you get the same measurement if...?
- **Record, Organize, and Display Data**
  Students determine what is to be measured before experimentation and construct a data table accordingly. Teachers suggest and model logical and meaningful ways of organizing and displaying data. Students transform raw data to reveal patterns, reveal relationships between variables, or clarify results. They record, organize, and display observations and data using an appropriate format, including point-form notes, diagrams, sentences, charts, lists, spreadsheets, graphs, and frequency tallies.

7. **Analyzing and Interpreting Design Results**
   In the analyzing and interpreting stage of the design process, students
   - identify patterns and relationships within results
   - identify problems with the prototype and suggest improvements
   - supply a rationale for making the necessary changes
   - evaluate strengths and weaknesses
   - critically assess and evaluate their own and others' products and systems, particularly for aesthetics, appropriateness, quality, resource usage, performance of materials, production methods, and economic and social considerations

Suggestions for Instruction

8. **Concluding and Applying**

   In the concluding and applying stage of the design process, students propose and justify a solution, identify new problems, and reflect on prior knowledge and experiences. They present an evaluation of their own and others' products, in which they address the relationship between materials chosen and procedures and processes used, note suggestions for and justification of possible improvements, comment on suitability of the product for manufacture, and estimate the effects and costs, including environmental and economic considerations.

   - **Communicate Methods and Results**
     Students communicate methods, results, conclusions, and new knowledge in a manner consistent with their target audience.
   - **Use Various Media to Communicate Results**
     Students may present their results in various ways.

     Examples of Media to Communicate Results:

     — **Formal Lab Report**

     — **Scientific Paper**

     — **Presentation**
       – multimedia effects

     — **Visual Displays**
       – bulletin boards
       – cartoons
       – charts
       – Concept Maps
       – demonstrations
       – diagrams
       – dioramas
       – graphs
       – maps
       – models
       – newspaper/magazine advertisements
       – posters
       – radio commercials
       – television commercials
       – videos

     — **Community Connection**
       – Invite local members of the community to share their technological problem-solving knowledge with the class. Students could also interview community members in their homes or workplaces about a problem they have been applying themselves to solve.
       – Organize field trips to facilities that demonstrate clearly how solutions to problems often rely upon the eventual development of new processes or technologies. For instance, some paper-recycling facilities are unique in their ability to "de-ink" paper fibre that has undergone xerography, the application of a baked carbon film.

     — **Journal Writing**
       – Compare and Contrast (*SYSTH* 10.24)
       – Concept Frame (*SYSTH* 11.36)
       – Concept Map (*SYSTH* 11.14)
       – Concept Overview (*SYSTH* 11.37)
       – Fact-Based or Issue-Based Article Analysis (*SYSTH* 11.40, 11.41)
       – RAFTS (Role-Audience-Format-Topic-Strong Verb) (*SYSTH* 13.23)
       – Reflect on and Respond to a Question
       – Word Cycle (*SYSTH* 10.21)
       – Word Glossary
   - **Demonstrate Operation of the Design**

Suggestions for Assessment

Learning outcomes addressed through the application of the design process, like other areas of the curriculum, are assessed for the acquisition of knowledge, skills, and behaviours. A variety of assessment practices can be applied to the performance of a design task, including teacher observation, questioning, and student learning logs or notebooks.

It is important that the focus of assessment be on the demonstration of learning that has occurred throughout the design process. Similarly, the solution should not be evaluated on whether it worked, but rather on the degree of its effectiveness in addressing the original problem. Because of the sequential and recursive nature of the design process, student self-assessment and peer evaluation are ongoing. The design process also provides opportunities for formative assessment so that the teacher can plan the next stage of instruction and learning.

In the evaluation stage of the design process, assessment focuses on the positive aspects of the solution. Through the use of probing and open-ended questions, the teacher can elicit further thinking on making improvements to enhance the solution and to enhance student understanding of the science knowledge connected to the design task. This will also provide indicators as to students' level of achievement related to the learning outcomes. Design notebooks, demonstrations, oral presentations using visuals, and multimedia presentations can provide records of student learning at each stage of the design process and assist in the assessment of student learning.

A brief list of assessment techniques that could be applied within the context of the design process follows:

- **Rubrics/Checklists**
  - — Developing Assessment Rubrics in Science (see Appendix 8)
  - — Assessment Rubrics (see Appendix 9)
- **Visual Displays**
- **Journal Writing**
  - — Journal Writing and Assessment (*SYSTH* 13.21)
  - — Word Cycle (*SYSTH* 10.21)
- **Research Reports/Presentations**
- **Performance Assessment**
- **Pencil-and-Paper Tasks**
  - — Compare and Contrast (*SYSTH* 10.24)
  - — Concept Relationship Frame (*SYSTH* 11.20, 11.35)
  - — Fact-Based or Issue-Based Article Analysis (*SYSTH* 11.40, 11.41)
  - — Word Cycle (*SYSTH* 10.21)

General Learning Outcome C	Specific Learning Outcome	
Students will… Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.	**SLO C3:**	Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.
	SLO C4:	Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.
	SLO C5:	Work cooperatively with others and value their ideas and contributions.

Suggestions for Instruction

Science, Technology, Society, and Environment (STSE) Issues and Decision Making

Students are increasingly confronted with questions that require the processing of information and demand the use of scientific thinking to make informed decisions. Given the opportunity, students should be able to make an informed decision based upon a methodology that is rational and scientific. Because students have different experiences and interests, they do not all view a problem in the same way. It is essential that educators provide students with opportunities to gain experience in mastering the skills of informed decision making.

Traditional decision-making models are focused on values, attributes, goals, alternatives, and *subjective mapping*. This mapping includes data collection, statistical analysis, and research models that help the decision maker evaluate possible alternatives. The subjective mapping between criteria and attributes is provided by the decision maker. To clarify the criteria that argue for a particular course of action, students need to know why certain criteria were necessary. The attributes of the problem to be solved ultimately drive the criteria used in assessing the situation.

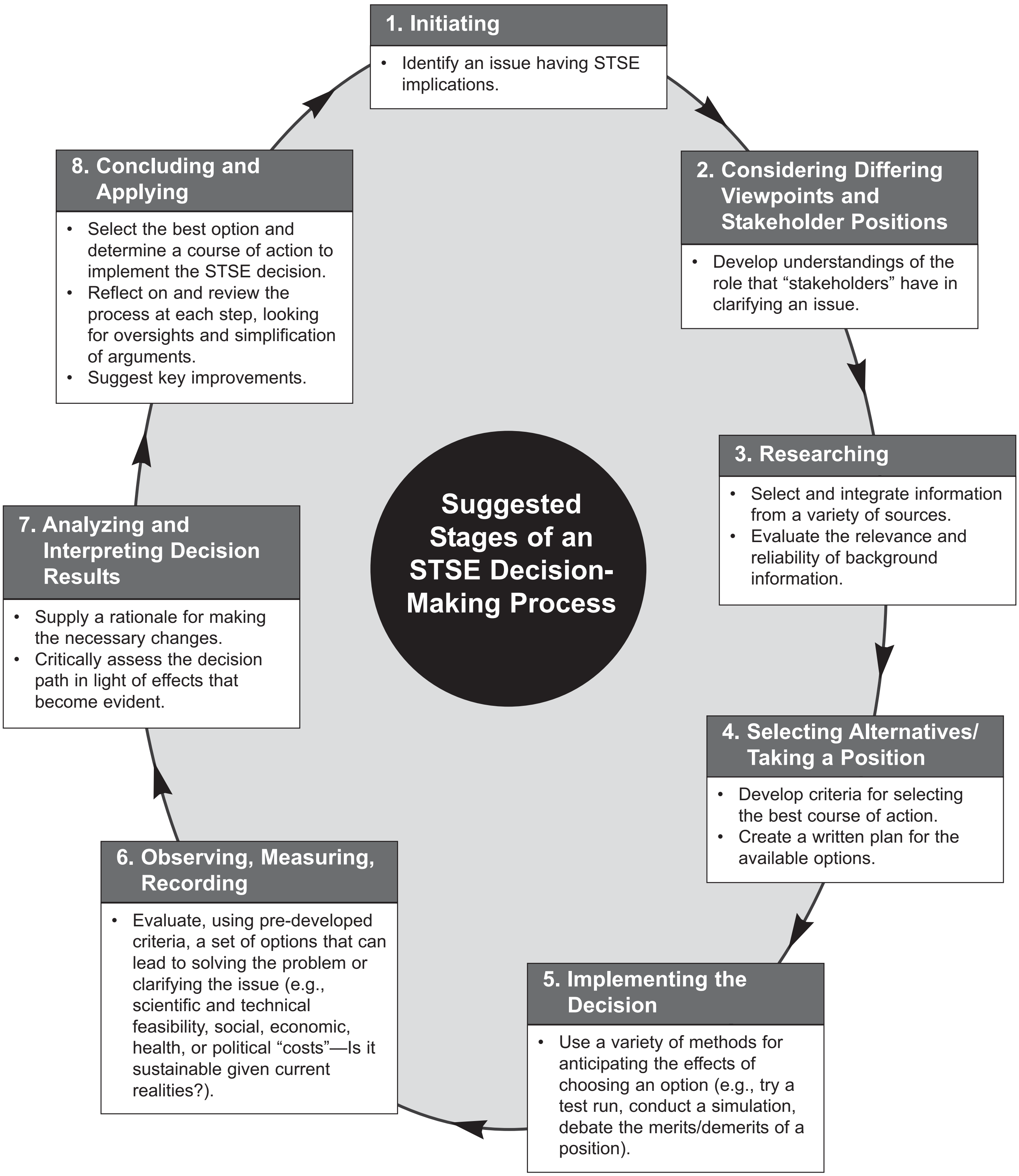
STSE understandings are an essential component of scientific literacy. An STSE approach fosters the development of citizens who are able to evaluate scientific information critically, understand the relationships amongst science, technology, society, and the environment, and make informed and responsible decisions, as well as act on these decisions. STSE issues are often complex, with no one right answer. They can also be controversial, as they deal with individual and group values. By their nature, STSE topics generate diverse opinions; individuals must question the distinctions between right and wrong, cost and benefits, and justice and injustice, and develop interpretations of fairness and tolerance. They include topics on which reasonable people may sincerely disagree. Students are encouraged to exercise both intellectual and ethical skills as they investigate the social and environmental impacts of scientific and technological developments (refer to *SYSTH* 4.4-4.5).

The decision-making process is a proposed approach for analyzing STSE issues and making a choice among different courses of action. To make an informed decision, students must understand scientific concepts involved in the issue and must be aware of the values that guide a decision. The process can involve a series of discrete steps, which may include those described on the following pages. One should also recognize that this is but one possible sequence—of a rather concrete nature—that has demonstrated its usefulness with student audiences. Teachers are encouraged to use this as a beginning template toward more sophisticated STSE approaches with Senior 3 students.

The diagram that follows illustrates the Stages of the Decision-Making Process: Toward STSE Thinking.

Suggestions for Instruction

Stages of the Decision-Making Process: Toward STSE Thinking



Suggestions for Instruction

The decision-making process involves the following stages:

1. **Initiating:** Identify and clarify the issue.
2. **Considering Differing Viewpoints and Stakeholder Positions:** Be aware of the different perspectives and interests involved in the issue.
3. **Researching:** Critically evaluate the available research.
4. **Selecting Alternatives/Taking a Position:** Determine possible alternatives or positions related to an issue.
5. **Implementing the Decision:** Evaluate the implications of possible alternatives or positions related to an issue.
6. **Observing, Measuring, and Recording:** Make use of criteria in order to assess the feasibility of a decision.
7. **Analyzing and Interpreting Decision Results:** Make a thoughtful decision and provide justification. Be aware of the values that may guide a decision.
8. **Concluding and Applying:** Act on a decision and then reflect on the process that led to a course of action.

Students have been introduced to the Decision-Making Model in Senior 1 Science. At Senior 3, in a curriculum such as Senior 3 Current Topics in the Sciences, students should be expected to deal with some larger-scale contexts, but the primary focus rests with local and personalized ones, to consider complex problems with *a small number of variables* and/or perspectives, and make their decisions based on extensive research involving some guided personal judgement. If students don't possess experience with an STSE decision-making model, teachers can start the process with some guidance, giving students a chance to use this approach in a structured environment. This could be done by giving them a specific scenario or issue to study. Students would eventually become active participants in the process, by choosing (individually, in small groups, or as a class) their own issues, doing their own research, making their own decisions, and acting on those decisions.

The decision-making process can be approached in a variety of ways. For instance, students can play the role of different stakeholders involved in an issue, work in small groups to discuss issues, or make a decision based on their own research and personal values. Students can be asked to take a stand and debate issues, or they can be placed in situations where they have to reach a consensus. Because there are so many different ways of approaching an issue, a variety of products or culminating events can result from a decision-making process (for example, a town hall meeting, a round table, a conference, a debate, a case study, a position paper, a class presentation, or a class discussion).

Regardless of what product students have to create or what event they have to participate in, questions such as the following can guide them in the decision-making process:

- What is the issue?
- What important scientific information is needed to understand this issue? Where can I find this information?
- Who has a stake in this issue? Why?
- What are the possible options?
- What are the pros and cons for each of the possible options?
- What is my decision? What criteria were used to make this decision?

Suggestions for Instruction

An STSE Decision-Making Guide

The Issue	State the issue in clear terms.
The Decision Question	The wording of the question is quite important, as it may affect the decision and ultimate outcomes.
Type of Decision Required	A question may involve • a scientific, technological, legal, political, or moral decision that is to be made • a public policy decision—a decision that prescribes ways of handling a situation of interest to the broader community
Possible Choices	Identify alternatives as they develop. Some decisions may have only two alternatives (for example, *build it* or *do not build it*), while others will have more than two.
Risk/Benefit Analysis	For each alternative, list the negative consequences and the positive consequences of taking the action.
Validity and Probability	Carefully check the *validity* of your risk/benefit arguments for each alternative. • Are your conclusions logical? • Are they based on false assumptions? • How *probable* are your conclusions in reality?
Values Assumed	Identify the values within each alternative. • Examples of values include: generation of capital (wealth) for a country, being in harmony with natural systems, causing no harm to people, practising justice, the rule of law, and honest intentions. • The values you include may not necessarily be your own personal values; nonetheless, you must recognize them and clarify them. • As you identify values, ask yourself questions. What things would people highly value if they strongly believed in Alternative 1 over Alternative 2?
Priority of Values	Rank the values that have been assumed in hierarchical order from most to least important.
Choice of Option(s) and Reason(s)	Weigh the consequences and consider the logic of your thinking, the probabilities, and your values. Then choose an option.
Action Recommended	Decide what action(s) should be taken, by whom, and when.

(continued)

An STSE Decision-Making Guide: Adapted from Aikenhead, Glen. *Logical Reasoning in Science and Technology*. Trial Version 2. Saskatoon, SK: Department of Curriculum Studies, University of Saskatchewan, 1987. Used with permission of Glen Aikenhead.

Suggestions for Instruction

An STSE Decision-Making Guide *(continued)*

Issue:			
Decision Question:			
Type of Decision:			
Possible Choices	**Risk/Benefit Analysis**	**Validity and Probability**	**Values Assumed**
Alternative 1	Negative Consequences:		
	Positive Consequences:		
Alternative 2	Negative Consequences:		
	Positive Consequences:		
Alternative 3	Negative Consequences		
	Positive Consequences		
Alternative 4	Negative Consequences		
	Positive Consequences		

(continued)

Suggestions for Instruction

An STSE Decision-Making Guide *(continued)*

Priority of Values (from most to least important):
Choice of Option(s) and Reason(s):
Action(s) Recommended (what, by whom, when):

Suggestions for Instruction

Overall Expectations

Students could achieve the identified learning outcomes through learning experiences such as the following:

- Know, respond to, and accept scientific inquiry as a means to developing new understandings of both the simplicity and complexity of natural systems.
- Model curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence.
- Use factual information, rational explanations, and persuasive argumentation when analyzing, evaluating, and communicating.
- Select and apply appropriate visual, numeric, graphical, symbolic, and linguistic modes of representation to communicate ideas, plans, and inquiry results effectively.
- Communicate questions, ideas, and intentions, as well as receive, interpret, understand, support or refute, and respond to the ideas of others. (For example: *Participate in a class discussion of the geological evidence suggesting that continental positions have changed in response to the mechanisms of plate tectonics or the expansion of the Earth.*)
- Select and integrate information from various print, electronic, and multimedia sources, and compile and organize information using appropriate formats and data treatments.
- Identify and apply criteria for evaluating evidence and sources of information, including the presence of bias.
- Work collaboratively in planning and carrying out investigations and in generating and evaluating ideas.
- Listen to, evaluate, and respond to the individual or group work of others, including an assessment of the credibility, accuracy, and potential biases of information presented.

Activating

Entry-Level Knowledge

- Students begin to make decisions based on scientific facts and refine their decision-making skills as they progress through the grades, gradually becoming more independent. Students also develop key attitudes, an awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning. Senior Years students recognize that STSE issues require a more sophisticated treatment through the decision-making process.

Prior Knowledge Activities

- Learning activities and strategies such as the following allow teachers and students to activate prior knowledge, recognize misconceptions, and relate new information to prior experiences.

  Examples of Strategies (See Appendices 2 and 3):

  — Anticipation Guide
  — Knowledge Chart
  — KWL
  — Listen-Draw-Pair-Share
  — LINK
  — Sort and Predict
  — Rotational Cooperative Graffiti

Vocabulary-Building Activities

- Learning activities and strategies such as the following allow teachers to assist students in accessing the vocabulary they already know or prepare them to learn vocabulary so that they will better understand new material.

  Examples of Strategies (See Appendix 3):

  — Sort and Predict
  — Three-Point Approach

Suggestions for Instruction

Acquiring and Applying Activities

Role-Play

Role-playing scenarios are designed to teach selected social processes that govern human relations, such as negotiating, bargaining, compromising, and developing sensitivity. Role-playing is an effective way to get students to examine the values of others and how those values guide decisions. Students should not always defend a point of view with which they agree. They need to put themselves in someone else's mindset, and speak from that individual's point of view during the activity. It is hoped that through this process students will gain an appreciation for the reasons why individuals hold divergent points of view. Ideally, the role-playing scenario will foster critical thinking skills, while promoting tolerance of alternative world views (see *SYSTH* 4.18).

- Role-playing activities can deal with many types of issues. For instance, a town-hall meeting activity could be used to deal with a local issue such as a proposed condominium development close to a city park (see teacher background on preparing activities for a town-hall meeting).
- Students could also take part in a role-playing activity in which a consensus between stakeholders must be reached, such as a round-table meeting or an international conference. The format would be similar to that of a town-hall meeting, but all stakeholders must come to a consensus. Explore with students what consensus means and how it differs from other forms of decision making.

Consensus is	Consensus is not
• based on identifying common ground	• based on majority rule
• reached by acceptable compromises	• reached by complying with the most outspoken group member
• always a decision that reflects the ideas and values of all group members	• always a decision that represents everyone's first choice

When studying STSE issues, a consensus approach can use the sustainable development model, which tries to achieve consensus by balancing the needs of human health and well-being, the environment, and the economy (see Manitoba Education and Training, *Education for a Sustainable Future* 14-16).

Town-Hall Meeting (Teacher Background)

1. Assign the role of different stakeholders (e.g., scientists, company executives, developers, Chamber of Commerce representatives, town residents, conservation officer, politicians, lawyers, environmentalist) to groups of students, and give them time to research and compile their arguments. They prepare a five-minute presentation to present their position, as well as notes to help them answer possible questions.
2. Prepare an agenda for the meeting, indicating a speaking order for the different stakeholders. As the moderator of this meeting, ensure that students respect the time given to present their position and give time for questions either after every speaker's presentation or after all stakeholders have presented their positions.
3. Give five minutes for every stakeholder to present and defend his or her position.
4. Stakeholders can then ask questions or direct comments to different stakeholders. To ensure that all students participate, focus part of their evaluation on their participation during the meeting.
5. Have students vote on the proposition at the end of the meeting (either with raised hands or with a secret ballot). Or, bring in a "town council," which could be another group of students from the class (who would write a report with their recommendation and impressions, indicating which stakeholders they believed and/or didn't believe and explaining why), from another class, or other teachers, administrators, or support staff.

Suggestions for Instruction

For examples of how the process could unfold in a classroom, refer to the activities suggested in the Appendices of this document. Any issue chosen by students could be addressed by using these types of activities. They could also be used as a guided activity to model a decision-making process before students study their own issues.

- Ask students about the importance of having everyone contribute during the role-playing activity (that is, hearing all voices). Have them answer questions such as the following in their science journals:
  - — Did you feel this situation actually occurred?
  - — Did you feel you were able to role-play well?
  - — Did you agree or disagree with the viewpoints of your character?
  - — What did you like or dislike about the activity?
- Students present their own view on the issue in a form such as a position paper, a letter to the editor, a news bulletin, and so on.

Online Resources for Role-Play

The following websites present ideas for role-playing activities.

ActionBioscience.org: <http://www.actionbioscience.org/lessondirectory.html>

Endorsed by the National Association of Biology Teachers, this website provides students and their teachers with opportunities to examine science content in the context of the scientific paper. The lessons are set up in such a manner that some interaction between the content of the scientific paper and the actual science content required for the classroom can be examined.

Australian Academy of Science. NOVA: Science in the News: <http://www.science.org.au/nova/topics.htm>

This website provides such a wide variety of topics and lessons (from mathematics, to physics, technology, biosciences, human health, the environment, and so on) that it will provide interesting current contexts for Senior 3 Current Topics in the Sciences for years to come.

Kemlitz, Judith, Michael O'Hare, and Dorothy Reardon. "Rainforests of Madagascar: Role Playing and Decision Making." Access Excellence @ the National Health Museum. 6 Jan. 2006 <http://www.accessexcellence.org/AE/AEPC/WWC/1991/rainforest_role.html>

In this "jigsaw-like" approach to threatened rainforests of the island of Madagascar, students develop their understanding of the skills and stakeholder positions often found in contentious issues. The results can be generalized across many similar situations related to environmental degradation.

Mills, Don. "Darwin/Lamarck Court Case." Access Excellence @ the National Health Museum. 6 Jan. 2006 <http://www.accessexcellence.org/AE/ATG/data/released/0078-DonMils/>

In this activity-based role-playing exercise, students take on the respective positions of Darwin and Lamarck (who were not contemporaries) in a courtroom setting. This debate format has become a favourite among teachers who appreciate the value of taking individuals out of time and artificially asking them to defend their ideas in front of their futuristic colleagues.

Nelson, Sharon. "Decisions, Decisions! A Genetics Role-Playing Activity." Access Excellence @ the National Health Museum. 6 Jan. 2006 <http://www.accessexcellence.org/AE/ATG/data/released/0350-SharonNelson/>

For this role-playing activity, students use research skills to investigate a particular human genetic disorder, and then develop a class presentation that explores bioethical considerations.

Suggestions for Instruction

Position Paper

A position paper is a written product that presents an opinion. Its goal is to convince others to agree with a point of view. A position paper can be assigned instead of role-play. It can also be assigned after role-play in order for students to write their own views on an issue. Position papers may contain a description of an issue and scientific knowledge surrounding the issue, arguments and evidence for both sides of an issue, a refutation of the opposing claim, and the viewpoint adopted, along with reasons why.

More detailed information about writing a position paper follows. An important component of this type of paper is the referencing of information and quoting of sources. The learning outcomes related to research and information management can provide useful strategies for teaching and assessing these skills.

Debating

Debates are effective at presenting diametrically opposed views related to STSE issues. For a formal debate, teams of students would either be assigned a position on a certain issue or they would choose a position with which they agree. Teachers can also ask a team of students to provide the necessary background for the audience to understand the topic before the formal debate begins. The presenters should go over the information with the debaters prior to the debate.

There are many possible formats for using debates in a classroom. Here is one example:

1. Initial presentation provides background so that the audience understands the topic (3 to 4 minutes).
2. First debater presents opening arguments (2 to 3 minutes). Arguments should be presented and supported with evidence such as statistics or quotes.
3. Second debater presents opening arguments (2 to 3 minutes).
4. First debater gives a rebuttal (1 to 2 minutes).
5. Second debater presents defending arguments (1 to 2 minutes).
6. Second debater gives a rebuttal (1 to 2 minutes).
7. First debater presents defending arguments (1 to 2 minutes).
8. Closing statements are presented (1 minute each).

Position Paper (Student Background)

- **Choosing an Issue for a Position Paper:** A good issue will have an element of controversy and will have at least two clear positions. Choose an issue that is of personal interest to you, and is manageable. You may already have an opinion about this issue, but you will need to research it to construct your arguments and to present a balanced view of the opposing position. After doing some research, your personal opinion about the issue might change. Listing pros and cons about the issue, along with evidence supporting the claims can help you in preparing your paper. Don't forget to reference the sources for all your information.

  You must also consider what audience you are writing for. Your task is to convince your audience to agree with your position; therefore, you must speak in a language that the audience will understand. For example, a paper written to convince your teacher would be written differently than a paper written to convince your friends.
- **Introduction:** Identify the issue and give some background information on it. What is the issue? Why is this issue important? What are some potential impacts of this issue? You can choose not to give opinions for or against the issue (just present the issue and its importance), or you can state your position without presenting all the supporting evidence for it. You want to create a context for your topic, stimulate the reader's interest about the topic, and then state your claim about the issue. The next step will be to provide some proof in order to support your claim.
- **Supporting Arguments:** Provide arguments that support the issue. You must provide evidence for your arguments (facts, statistics, authoritative testimonies). Leave out your opinions. Be thorough and fair and always cite your sources. You can directly quote from them or refer to them. Don't forget to jot down information in order to create a bibliography. The reader of your paper has to know where your evidence comes from. You must use at least three different sources when presenting the supporting arguments.
- **Opposing Position:** Present arguments for the opposing position. You must provide evidence for the arguments. Leave out your opinions. Use at least three different sources when presenting the arguments against an issue. It is best to choose one or two arguments and then develop them in depth.
- **Your Position:** State a position, along with a justification. This is where you can voice your own opinions. You can also refer to the facts, opinions, or data mentioned in the other parts of your position paper.

Suggestions for Instruction

Case Studies

Using case studies has the advantage of giving students a high degree of specificity and structure, while allowing them considerable input.

To develop or choose case studies that draw students into assignments and make them feel they are involved in authentic, relevant situations, teachers may find the following suggestions helpful:

- Ensure that each assignment is *relevant*. Students should feel that it is a typical, realistic example of a situation they may conceivably encounter after they graduate.
- Clearly *establish the purpose* of the assignment. Never let students feel that an assignment is of a "make work" nature.
- Ensure that the background is developed thoroughly, so that students will have a solid "feel" for the situation.
- *Make students work*. Rather than presenting students with information that they can simply regurgitate, let them tussle with numbers, research facts, and reach a decision.
- Add a touch of drama. *Create interest* by choosing or writing assignments that read like a short story. Introduce a human element, so that students can relate to the people they have to write about or from whom they supposedly drew information.
- Whenever possible, *use dialogue* or choose case studies that contain dialogue rather than simple narrative descriptions. Students can too easily copy segments of narrative, but cannot readily copy dialogue. Dialogue is more difficult to write, and takes more space on the assignment page, but it forces students to search for and extract relevant facts.

Online Resources for Case Studies

The following websites present case studies or ideas for developing case studies.

Access Excellence @ the National Health Museum Activities Exchange. Access Excellence Activities Collection: <http://www.accessexcellence.org/AE/index.html>

This website contains an extensive archive of student activities connected to the life and physical sciences. There is something for just about everyone here if one is willing to browse the many links available.

Cal State Fullerton. Physics 301—Energy and the Environment. Energy and Environment Cases: <http://energy.fullerton.edu/case-ideas.html>

This website features five case studies related to energy sources and the environment. These range from the prospect of electric-only vehicles to global climate change, to coal power versus nuclear generation. The website has a physics/engineering focus.

ETHEX (Exploratorium's Ethical Scenarios Forum). Diving into the Gene Pool: <http://www.exploratorium.edu/genepool/ETHEX.html>

This website offers teachers three case study scenarios dealing with science ethics, primarily in the areas of genetic testing, genetically modified foods, and possible improprieties in the use of information related to genetic manipulation.

Kennesaw State University. ChemCases: Decision Making and Technology: <http://science.kennesaw.edu/~mhermes/chem.htm>

This website consists of a series of curriculum supplement cases to be used in teaching a general chemistry course with a science/engineering focus. Each case study features foundational principles typically addressed in a traditional general chemistry curriculum. These cases then address the decision making that influences development of new consumer, agricultural, and pharmaceutical products. The cases provide students with opportunities to flex the components of the STSE decision-making process in the Manitoba curriculum.

The McGraw-Hill Companies. General and Human

Suggestions for Instruction

Biology. Bioethics Case Studies: <http://www.mhhe.com/biosci/genbio/olc_linkedcontent/bioethics_cases/>

This website links to a large number of different case studies developed for courses that relate to human biology. Among these are links to stem-cell research, artificial *in utero* techniques, embryo research, sports issues, HIV/AIDS, osteoporosis, and many other areas.

National Center for Case Study Teaching in Science. Case Method Teaching: <http://ublib.buffalo.edu/libraries/projects/cases/teaching/novel.html>

James B. Conant of Harvard University was among the first science educators to use historical case studies in his teaching as a means of connecting science content *contextually*. For teachers interested in problem-based learning (PBL) techniques, this website is a veritable mine of information and analysis of the case-study teaching and learning style.

SCOPE (Science Controversies On-line Partnerships in Education). Genetically Modified Food: <http://scope.educ.washington.edu/gmfood/>

The advent of genetically modified (GM) foods in the human food chain at the grocery store has resulted in much public debate, scientific discussion, and coverage in various communication media. This website offers FAQ pages and web links to the issue of genetically modified organisms (GMOs) in our food supply.

University at Buffalo. The National Center for Case Study Teaching in Science Case Collection: <http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm>

This website provides numerous examples of science case studies developed by teachers for teachers. Copyright for most of these cases is held by the National Center for Case Study Teaching in Science. This body encourages educational, not-for-profit use of their cases by individual instructors. If teachers plan to use the cases from this website in their classrooms on this basis, they do not need to contact the National Center for Case Study Teaching in Science for permission. However, reproduction of any case in the collection in a printed work (such as a course-pack) or republication onto a website requires permission. Teachers will need to *register* with a valid email address to obtain a password for entry and downloading. The opportunity to submit cases to this organization for upload to the website also exists.

University of Delaware. Problem-Based Learning (PBL) Clearinghouse: <https://chico.nss.udel.edu/Pbl/index.jsp>

This website, which requires teachers to generate a user name and a password, directs its energies toward a problem-based learning (PBL) model that has gained credence in recent years among educators. The PBL Clearinghouse offers a collection of problems and articles to assist educators in using problem-based learning. The problems and articles are reviewed by experts in the science content areas. Teaching notes and supplemental materials accompany each problem, providing innovative and classroom-tested insights and strategies. Access to the Clearinghouse collection is limited to educators who *register via an online application*, but the materials are free, and no obligation exists beyond the fair classroom use of these materials.

Suggestions for Assessment

Role-Play

Use a presentation rubric for the role-playing activities. Peer-assessment could be used for evaluating the activities. Criteria should be developed with students and should include both content and presentation components such as the following:

- Position is clearly stated.
- Evidence is presented to support arguments.
- Answers to questions are clear and aligned with the position of the stakeholder.
- Presentation is clear and organized.
- Position of stakeholder is accurately represented.
- Personal biases are absent.
- Language and attitude are appropriate.

Debates

- Use a rubric for assessing the debate. A suggested rubric can be found below.
- Students peer-assess the debating skills of their classmates using criteria that were developed in advance with students.

Position Paper

Use a rubric for assessing the position paper. Criteria for the activity should be developed with students and could include components such as the following:

- Position is clearly stated.
- An understanding of the scientific knowledge surrounding the issue is evident.
- Evidence is presented to support arguments.
- Opposing claims are presented along with evidence to support them.
- Reasons are given for not agreeing with opposing claims.
- Paper is well organized and clearly demonstrates an understanding of the issue.
- Data and others' work are clearly referenced.
- References are written in the correct format.

Students can be asked to present their position to the class. A presentation rubric can be used to assess this work.

Debating Rubric

Criteria	Exemplary 4	Accomplished 3	Developing 2	Beginning 1
Organization of Opening Statement	Always maintains focus on the topic.	Usually maintains focus on the topic.	Sometimes maintains focus on the topic.	Does not maintain focus on the topic.
Use of Evidence to Support Claims	Always uses evidence to support claims.	Usually uses evidence to support claims.	Sometimes uses evidence to support claims.	Does not use evidence to support claims.
Persuasiveness	Arguments are clear and convincing.	Arguments are usually clear and convincing.	Arguments are sometimes clear and convincing.	Arguments are not clear and not convincing.
Teamwork	Always uses team members equally effectively.	Usually uses team members equally effectively.	Sometimes uses team members equally effectively.	Does not use team members equally effectively.
Organization of Closing Statement	Always responds with points that are specific to the topic.	Usually responds with points that are specific to the topic.	Sometimes responds with points that are specific to the topic.	Does not respond with points that are specific to the topic.

Suggestions for Assessment

Case Studies

Brainstorm with students to determine what criteria should be used to evaluate responses to questions in a case study. Criteria could include the following:

- Response clearly answers the question.
- Response uses evidence to identify issues referred to in the question.
- Response justifies suggested course of action using evidence.

Rubrics/Checklists

- Developing Assessment Rubrics in Science (see Appendix 8)
- Assessment Rubrics (see Appendix 9)

Journal Writing

- Journal Writing and Assessment (*SYSTH* 13.21)
- Reflection on debate (What surprising points were raised during the debate? Do you think there is a right or wrong answer? What valid facts were used to support the arguments? Summarize the arguments given by each team.)
- Word Cycle (*SYSTH* 10.21)

Performance Assessment/Collaboration

The focus for assessment of skill-related learning experiences can be on performance and collaboration, as well as the understanding demonstrated by the student's ability to relate observations to their knowledge base. The teacher should specify, in advance, what the focus will be.

For instance, if students were asked to demonstrate their understanding of movement of substances across a cell membrane, the following items could be useful:

- Provide *unlabelled* diagrams of active transport diffusion and osmosis. Students identify what each represents and explain what is happening.
- Compare and contrast passive and active transport.
- Draw a Concept Map to illustrate how materials move in and out of a cell.
- Explain why the ability to regulate the movement of materials into and out of the cell is important. (In their response, students should refer to life processes and the concept of homeostasis.)

Pencil-and-Paper Tasks

- Word Cycle (*SYSTH* 10.21)
- Compare and Contrast (*SYSTH* 10.24)
- Concept Relationship Frame (*SYSTH* 11.20, 11.35)
- Fact-Based or Issue-Based Article Analysis (*SYSTH* 11.40, 11.41)

Teacher Notes

General Learning Outcome D

Essential Concepts

GLO D

Explore, understand, and use scientific knowledge in a variety of contexts.

Overview

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge. Many of the following suggestions for instruction have been developed from the recommendations found in the *Pan Canadian Science Framework* (Council of Ministers of Education, Canada). Teachers are encouraged to access this document to develop a greater appreciation for the changing role and purpose of acquiring scientific knowledge in today's school science environment.

The subject matter of science includes theories, models, concepts, and principles that are essential to a working understanding of the life sciences, physical sciences, geosciences, and space sciences. Content knowledge can provide an informed basis for exploring essential learning, and it will be increasingly important for students of science to make interdisciplinary connections among and within the science disciplines. Ultimately, we desire to answer for a particular place and time the question: "What knowledge from science is of most worth?" There is no definitive answer to such a complex and opinion-ridden question, and so we leave this to the professional discretion of those particular places and the students who live in them.

Specific Learning Outcomes

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.

SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

General Learning Outcome D

Students will...

Explore, understand, and use scientific knowledge in a variety of contexts.

Specific Learning Outcome

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

Suggestions for Instruction

Similarity and Diversity

The concepts of similarity and diversity provide tools for organizing our experiences with the world. Beginning with informal experiences, students learn to recognize attributes of materials that help to make useful distinctions between one type of material and another, and between one event and another. Over time, students adopt accepted procedures and protocols for describing and classifying objects they encounter, thus enabling them to share ideas with others and to reflect on their own experiences (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Analyze the patterns and products of evolution.

Science attempts to provide an explanation for the origin and evolution of life on Earth. Evidence for evolutionary change can be found in things such as fossil records, plate tectonics, and DNA samples.

Activating Prior Knowledge

- Students discuss possible evolutionary relationships between familiar groups of organisms, such as mammals or flowering plants. *What structural features have changed the most over time? What evolutionary evidence exists for the ancestry of a modern animal or plant?*

Acquisition and Development of Concepts

- Students trace the ancestry of the modern horse from Eohippus(?), which may never have existed, to Equus to determine the historical changes required in its evolution from a small, woodlands browser to a large, plains-dwelling grazer. If students are provided with illustrations (drawings, photographs, art) that compare possible changes in anatomy, such as size, leg anatomy, and tooth anatomy, they can evaluate evidence for the theory of evolution. *How are dietary changes linked to changes in tooth anatomy? What advantages would a tall horse have as a plains dweller? Why would running be necessary for a plains dweller? How did changes in the environment result in an evolutionary adaptation?*
- Students research and develop a large timeline, drawn to scale, showing the history of the science of evolution (dates, major advances in evolutionary knowledge, names).
- Students research and debate Lamarckism versus Darwinism.
- Students choose a common structure, such as bird beaks or wings, and compare the evolutionary adaptations between species.

Application

- Students investigate and report on the evolution of the cat, dog (or other household pets), and/or other domesticated animals used in agriculture.
- Students visit a local museum that contains the paleontological story of various animals or plants.
- Students videotape and share with the class a story of a chosen organism.
- Students investigate the role of mitochondrial DNA in the study of evolution.
- Students investigate the role of humans in the evolution of the modern dog.
- Students examine the chemical composition of an evolutionarily similar structure such as hair, nails, and feathers.

Suggestions for Instruction

Illustrative Example 2:

Identify and explain the diversity of organic compounds and their impact on the environment.

Organic chemistry is an important component of the study of biochemistry, bioengineering, medicine, and synthetic chemistry. Students should be aware of the process whereby carbon-bearing resources are converted into basic organic molecules that are then turned into a wide variety of plastics, fuels, and pharmaceuticals.

Activating Prior Knowledge

- Students identify different synthetic organic compounds in their classroom, in their homes, and in the environment. As well, students identify how many of the organic compounds are harmful or helpful to living things. *What are the risks and benefits to society and the environment of developing new synthetic products?*

Acquisition and Development of Concepts

- Students study the unique properties of carbon, focusing on the bonds that form between carbon atoms. Bond characteristics that may be considered include: strength, numbers (single, double, or triple bonds), and structure (long, straight, or branched chains or ring). Students build, draw, and name models of a variety of organic compounds.
- Students research the historical development of medicinal products, starting with crude extracts from plant sources. *Why are plants valuable resources? What are some modern medicines that have been developed from ancient remedies? What are the active ingredients? What are the different purifying methods?*

Application

- Students carry out a risk-benefit analysis of activities that produce dioxins as by-products. These activities could be the burning of household waste in the backyard, the incineration of toxic wastes, or various industrial processes. *What effect do dioxins have on living organisms?*
- Students choose a synthetic material and carry out a practical investigation of some of its properties, such as physical strength, effect of solvents, and combustibility. In conjunction with the investigation, students obtain and present information related to the properties, cost, uses, possible hazards, means of production, and social and economic implications of the chosen material.
- Students synthesize an organic compound such as acetylsalicylic acid (ASA), nylon, or an ester.
- Students draw the chemical structure of medicinal compounds and describe the specific part of the structure that is associated with its medicinal activity.

Illustrative Example 3:

Demonstrate an understanding of solutions and stoichiometry in a variety of contexts.

It is important for students to understand that most chemical reactions involve chemicals dissolved in a medium, such as water. Learning opportunities involving the nature of solutes, solvents, the mole concept, balancing equations, and stoichiometry enable students to gain a better understanding of the nature of chemical reactions.

Activating Prior Knowledge

- Students compare properties of different kinds of solutions using various technologies, and establish classes of solutions, such as electrolyte/non-electrolyte or acid-base. The importance of controlling concentration can be illustrated by reminding students that a very low fluoride ion concentration is beneficial since it inhibits dental decay, but a concentrated fluoride solution is highly toxic. *Why is the ability to predict the type and quantity of products in a reaction important for a scientific investigation or a chemical-industrial process?*

Acquisition and Development of Concepts

- Students perform calculations dealing with molar concentration of a solution, leading to the preparation of an ionic solution of known concentration. The use of appropriate equipment, such as a balance, volumetric flask, funnel, and beaker, to prepare such a solution should be emphasized.

Suggestions for Instruction

- Students predict, using the method of stoichiometry, the quantity of a reagent used or produced in a chemical system, given a specific quantity of another reagent used or produced in that reaction.
- Students perform quantitative investigations to test the predictive ability of the stoichiometric method and quantitative analyses to determine an unknown quantity in a chemical system, such as the unknown concentration of a solution or the unknown mass of a solute.

Application

- Students discuss with an industrial chemist the usefulness of the stoichiometric method in science and technology in industrial applications.
- Students research the importance of stoichiometry in pharmacology.
- Students determine, based on chemical composition, why certain foods are more efficient at providing energy than others.
- Students determine, based on stoichiometric principles, what type of heating system is the most efficient to install in a home.
- Students investigate how airbag designers use stoichiometry to determine the right composition of gas.

Illustrative Example 4:

Describe the nature of space and its components and the history of the observation of space.

The stars and other celestial objects have long held a fascination for humans. From the earliest times of recorded history, humans have attempted to explain what is in space. Through various learning activities, students identify and describe the various components of the universe and develop an appreciation of the vast distances between these components.

Activating Prior Knowledge

- Students engage in a general discussion or brainstorming session about the nature of the universe. This should lead to the identification of recent advances in technology, such as optical, radio, and orbiting telescopes, that have allowed astronomers to observe the various components of the universe and to speculate on what has happened in the past and what might happen in the future. *How are other stars similar to and different from the sun? What do we know about the universe? What are we trying to find out?*
- Students develop a chronology of space discovery and exploration.

Acquisition and Development of Concepts

- Students use the Hertzsprung-Russell diagram to study theories of stellar evolution. This could lead to a discussion of the frequency of stars similar to our sun and the possibility and probability of other planets similar to Earth.
- Students develop an appreciation of the size of the universe and the vast number of stars and other components. Students should be able to understand the idea that because of the vast distances in space, the light reaching our eyes and our instruments is millions of years old, and therefore our present view of distant objects in space is actually a look back in time.
- Students examine the Nebular Hypothesis of the formation of the solar system.
- Students investigate the relationship between Earth and its single moon. *How and why are they different? How did they come to orbit around each other?*
- Students find out how astronomers determine the composition, age, and history of a planet or a star.

Application

- The study of star formation and evolution may help students understand the chemistry of Earth's rocks, air, water, and life. Students speculate about the possibility of life elsewhere in the universe. This could lead to a discussion of the necessary requirements for human life, and of the idea that different life forms may have different requirements.
- Students investigate the possibility of living in space.

General Learning Outcome D	Specific Learning Outcome
Students will… Explore, understand, and use scientific knowledge in a variety of contexts.	**SLO D2:** Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

Suggestions for Instruction

Systems and Interactions

An important part of understanding and interpreting the world is the ability to think about the whole in terms of its parts and, alternately, about parts in terms of how they relate to one another and to the whole. A system is a collection of components that interact with one another so that the overall effect is much greater than that of the individual parts, even when these are considered together (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Compare and contrast mechanisms used by organisms to maintain homeostasis.

Note: This topic is treated in significant detail in Manitoba's Senior 3 Biology curriculum. Teachers are encouraged to consult *Senior 3 Biology: A Foundation for Implementation* (Manitoba Education, Citizenship and Youth) for detailed approaches to the topic.

All living organisms struggle to maintain an internal balance in response to the constant pressure of external phenomena. Students should be provided with a variety of opportunities to study different factors affecting an organism's homeostasis. Through this study, students begin to appreciate the complexity of mechanisms involved in homeostatic regulation.

Activating Prior Knowledge

- Students discuss how organisms (plants and animals) survive some of the severe weather and climate conditions in Canada. *How do plants use homeostatic mechanisms to adapt and survive? What adaptive mechanisms have been developed by organisms such as fish, frogs, and plants to survive in extreme weather conditions?*

Acquisition and Development of Concepts

- Students research, design, and/or conduct experiments to investigate: the transpiration tension theory of vascular plants; behavioural adaptations; tropisms such as hydrotropism, geotropism, chemotropism, and phototropism; and the effect of growth hormones on plants.
- Students inquire into the following question: *How do gardeners, horticulturalists, agriculturalists, and tree technologists promote plant adaptation and survival for use by human communities?*
- Students choose a particular animal species and investigate an environmental adaptation (for example, to heat, cold).
- Students discuss the importance of wetlands in maintaining homeostasis in the environment.

Extension

- The University of Manitoba operates a Laboratory for Exercise and Environmental Medicine, in which Dr. Gordon Giesbrecht studies human responses to exercise/work in extreme environments. He has conducted hundreds of cold water immersion studies that have provided valuable information about cold stress physiology and pre-hospital care for human hypothermia. Dr. Giesbrecht has undertaken a number of unique projects, such as a Lake Winnipeg Marathon on Ice. Students may be interested in finding out what Dr. Giesbrecht's most current project is.

  Contact information:

  Dr. Gordon Giesbrecht
  Faculty of Physical Education and Recreation Studies
  University of Manitoba
  Email: giesbrec@ms.umanitoba.ca

Suggestions for Instruction

Application

- Students choose a plant, propagate it, and assist its homeostatic mechanisms to help the plant survive in the conditions of its home.
- Students research hardiness zones in Canada, and describe how some plants can survive in certain zones when others cannot.
- Students examine what happens when kidneys malfunction in a human.
- Students research the contribution of the immune response to homeostasis.

Illustrative Example 2:

Evaluate relationships that affect the biodiversity and sustainability of life within the biosphere.

Note: This topic is a primary focus of Manitoba's Senior 4 Biology curriculum. Teachers are encouraged to consult *Senior 4 Biology: A Foundation for Implementation* (Manitoba Education, Citizenship and Youth) for detailed approaches to this topic.

At the biome and ecosphere levels of biological organization, there are many complex interactions between biotic and abiotic factors. Building on their understanding of ecosystems and certain principles of population dynamics, students need to understand the many interrelationships affecting population growth.

Activating Prior Knowledge

- Taking an example of a local/regional endangered species, students review the determiners of population: natality, mortality, emigration, and immigration. Students then brainstorm factors that affect human natality and mortality. *Why should we be concerned about Earth's carrying capacity for the human population?*

Acquisition and Development of Concepts

- Students use graphs located in resource materials or constructed from data tables to illustrate the historical growth of human population based on estimated data. They project the graph line into the future as an exercise of prediction and extrapolation in terms of linear or exponential growth and doubling of time.
- Students obtain and graph data of a particular species of organism, such as a local fish, and then interpret the graphs.
- Students research and debate the role of zoos in maintaining biodiversity.

Application

- Students identify which social and environmental factors need to be considered and changed locally, regionally, and globally to create a sustainable human population for planet Earth.
- Students research and then debate the ethics of human population control.
- Students plan and carry out a terrestrial or an aquatic biodiversity study.
- Students use environmental census data to study the state of a threatened species and present a plan to maintain the species.

Illustrative Example 3:

Demonstrate an understanding of the characteristics and interactions of acids and bases.

Students regularly use solutions that include acids and bases. It is important that they be able to demonstrate their understanding of acids and bases by appropriately selecting the proper acid and base to use for a given task. As well, students should be aware of the potential effects these chemicals could have on the environment. Students' knowledge and interests are enhanced when they understand the relationship between acid-base theories and certain acid-base reactions that take place around them.

Activating Prior Knowledge

- Students identify common products involving acids and bases, such as shampoos, foods, and household cleaners. They should be encouraged to speculate as to how acids and bases react in the situations they identify. *Why are specific acids and bases used in particular instances?*
- Students research and discuss the causes and effects of acid rain.

Suggestions for Instruction

Acquisition and Development of Concepts

- By studying the historical development of acid-base theory, students will be able to show how theories evolve in light of new experimental evidence.
- Students formulate an operational definition of acids and bases based on laboratory observations.
- In a laboratory setting, students determine the concentration of an acid or a base, the citric acid concentration of a citrus fruit, or the acetylsalicylic acid (ASA) content of a headache medication tablet.

Application

- Students address an environmental issue pertaining to acids and bases. Working as a team, they present factual arguments representing various perspectives.
- Students examine how the understanding of the chemistry of hair care, including pH, helps in the development of better hair-care products.
- Students determine how the acidic or basic nature of soils is important in the growth of food crops.

Illustrative Example 4:

Illustrate and explain the various forces that hold structures together at the molecular level, and relate the properties of materials to their structures.

Modern chemistry is directly involved in the development of new materials. Depending on their intended applications, materials can now be synthesized according to specific properties such as weight, resistance to heat, flexibility, malleability, and electrical conductivity. To synthesize a new material, it is often necessary to have an understanding of the electron arrangement, and thus the type of bonding, in the material. For students, knowledge of the nature of bonding is important because bonds are ultimately responsible for a substance's physical and chemical properties.

Activating Prior Knowledge

- Students identify changes in the composition of materials and the structure of common objects. The evolution of the bicycle and the automobile are good examples of how characteristics of materials, such as being lightweight and rust-resistant, have improved the efficiency of these vehicles. *What other materials demonstrate useful properties? How does the nature of bonds determine a material's properties?*

Acquisition and Development of Concepts

- Students predict and explain the different types of intramolecular forces and intermolecular forces for a given compound. They use accepted models to illustrate these forces. They also use established conventions to name and represent the studied compounds. Important work by scientists relating molecular structure to its properties can be emphasized in this area of study.

Application

- Students research some modern materials, such as composites, resins, alloys, and ceramics, and relate the properties of these materials to the bonds.
- Students research and design a structure, such as a bridge, where the type of material used is critical in its construction.

Illustrative Example 5:

Explain the fundamental forces of nature, using the characteristics of gravitational force and electric and magnetic fields.

Television is used in conjunction with video cameras, videodiscs, and videocassette recorders for a wide variety of purposes, including entertainment, education, engineering, and medicine. These electrical devices use the principles of electromagnetism and energy to produce an image on a screen. Students should be able to apply these principles to the functioning of TV picture tubes.

Suggestions for Instruction

Activating Prior Knowledge

- Using a direct current (DC) power source, wire, solenoid, and compass, students investigate the characteristics of magnetic fields. Using an electron tube, they can observe the effects of a magnet on the electron beam.
- Students use print and electronic sources to investigate the development of television/LCD flat-screen technology. *Is the quality of the image produced by a 27 in. (68.6 cm) screen better than that produced by a 54 in. (137.2 cm) screen? Why?*
- Students examine the gravitational forces affecting planets and satellites in the solar system. *How do gravitational forces affect us daily?*

Acquisition and Development of Concepts

- Students analyze, both qualitatively and quantitatively, the forces produced as a result of electric current flowing through a wire. They determine what factors are responsible for increasing and for decreasing the force on the moving charge.
- Students develop a plan to compare the quality of the picture for smaller and larger screen sizes by identifying specific major variables and criteria.
- Students describe the role of magnetism in solar phenomena such as sunspots.

Application

- Students list the design difficulties involved in manufacturing a 54 in. (137.2 cm) flat-screen TV compared to those involved for a 27 in. (68.6 cm) screen, as well as the changes that would need to be made to the design if the quality of the picture for a 54 in. (137.2 cm) set were to match that of a 27 in. (68.6 cm) set.
- Students determine whether it would be in a buyer's best interests if the flats-screen TVs manufactured for North America renewed the colour screen 60 times a second, rather than the current 75 times per second.
- Students explain the synchronization of the cathode-ray tube with TV cameras and TV sets.
- Students plan a trip near a black hole. What will be the effect of the *gravitational force?*
- Students research the role of the magnetic field on animal migration.
- Students build a solar cell, explaining how light energy is converted into electric energy.
- Students explain how a microwave works.

Illustrative Example 6:

Describe and predict the nature and effects of changes to terrestrial systems.

Earth contains a variety of complex, yet interconnected, systems. The major systems are generally referred to as Earth's spheres: atmosphere, hydrosphere, lithosphere, and biosphere. Within each sphere are other systems or subsystems.

Activating Prior Knowledge

- Students investigate each of Earth's systems to identify their general characteristics. These investigations could include: monitoring weather patterns using appropriate tools and procedures; identifying and classifying rocks and minerals; analyzing oceanographic data; and studying local examples of erosional activity. *How do the atmosphere and hydrosphere interact in the water cycle?*

Acquisition and Development of Concepts

- Students describe the physical processes of evaporation, condensation, and precipitation, including the energy transferral that takes place in each process. Using this information, they explain common weather phenomena such as rain, thunderstorms, hurricanes, and tornadoes. They should be able to demonstrate an understanding that, while the hydrosphere and the atmosphere may be described separately, they are inextricably linked.
- Students write a story from the perspective of a water molecule and, in the context of the story, thoroughly explain the water cycle.
- Students go on a field trip to examine local effects of erosion.

Suggestions for Instruction

Application

- For outdoor activities, knowledge of the weather and weather systems is very useful. To become familiar with predicting weather, students develop possible weather scenarios describing some atmospheric conditions. They then challenge classmates to predict what the effects of those conditions could be on weather for the short term and the long term.
- Students develop a plan to control erosion in a local area.

Illustrative Example 7:

Demonstrate an understanding of the formation of Earth, its history, and its geologic change.

Recent scientific and technological developments have enhanced our understanding of the history of Earth, but at the same time they have raised more questions. Since the human perception of time deals with relatively short periods, geologic time is a difficult concept for students to understand and appreciate. However, the concept of geologic time is critical for understanding concepts such as the formation of planets, the movement of continents, the changing of climates, the evolution of organisms, and the development of mountains.

Activating Prior Knowledge

- Students participate in a discussion of different explanations of the origin and the age of Earth, from religious and cultural explanations to the big-bang theory. In exploring these ideas, students need to examine the evidence that has been collected to support the various explanations and to make their own judgements about the relative merits of each. *How have science and technology helped humans attempt to determine particular events in Earth's history?*

Acquisition and Development of Concepts

- Relative ages of rocks and events in Earth's history can be determined by applying basic Earth science concepts such as uniformitarianism, original horizontality, and superposition. To determine relative dating or sequencing of events, students should examine and interpret geological cross-sections that exhibit folding, faulting, intrusions, and erosion.
- The age of individual events or objects from Earth's history can be determined by various radiometric dating techniques.
- A radioactive decay simulation activity using coins or other appropriate objects would help students understand the concepts of radioactive decay, isotopes, and half-lives.

Application

- Students analyze a fictional geological cross-section and use other data generated by relative dating to identify the age of particular fossils.
- Students research and debate issues surrounding climate change.

Illustrative Example 8:

Demonstrate an understanding of the relationships among systems responsible for changes to Earth's surface.

Geophysical studies of Earth have generated evidence that Earth's interior is a dynamic, moving environment that has caused mountains to rise, basins to sink, and entire land masses to move, resulting in continual rearrangement of the surface of the continents and the configuration of the oceans. These processes, which modify the shape of Earth's surface, form the basis of the plate tectonic theory. Students can develop an understanding of plate tectonic theory by examining various Earth processes.

Activating Prior Knowledge

- Students identify the location of global features such as mid-ocean ridges, marine trenches, island arcs, mountains, and volcanoes, and hypothesize why these features are located where they are. *How does an understanding of plate tectonic activity benefit humankind?*

Acquisition and Development of Concepts

- Students study the distribution of global features such as mid-ocean ridges, marine trenches, island arcs, mountains, and volcanoes.

Suggestions for Instruction

- Students analyze the types of plate margins and correlate various features with a specific type of margin.
- Students use the Internet to gather information about recent earthquake or volcanic activity, or about other risks associated with geological processes.
- Students explore the tools and techniques used to study the processes that change the lithosphere. These tools and techniques could include aerial photographs, satellite photographs, computer-enhanced images, radar, and computer modelling.
- Students analyze seismographic data to determine the epicentre of an earthquake.

Application

- Knowledge of earthquakes and information gathered from past experience may be used to create an emergency-response plan for a community located in a geologically active area.
- Students devise a set of construction guidelines for public buildings or homes, or guidelines governing the types of housing allowed in a geologically active area.

Teacher Notes

General Learning Outcome D	Specific Learning Outcome
Students will… Explore, understand, and use scientific knowledge in a variety of contexts.	**SLO D3:** Understand the processes and conditions in which change, constancy, and equilibrium occur.

Suggestions for Instruction

Constancy and Change

The concepts of constancy and change underlie most understandings of the natural and technological world. Through observations, students learn that some characteristics of materials and systems remain constant over time (e.g., the speed of light or the charge on an electron), whereas other characteristics change. Through formal and informal studies, students develop an understanding of the nature of things, and of the processes and conditions in which change takes place (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Compare and contrast the reproduction and development of representative organisms.

Reproduction is an essential process for all living organisms. Besides understanding some principles of how living organisms reproduce, students can begin to appreciate the complexity and impact of reproductive technologies. Analysis, from a variety of perspectives, of the risks and benefits of these technologies creates opportunities for students to apply scientific knowledge, skills, and attitudes in meaningful situations.

Activating Prior Knowledge

- Animal husbandry has revolutionized the use of in vitro fertilization techniques. The reproductive rates of valuable livestock have increased dramatically, as have beneficial traits in new breeds. Students consider the following techniques and identify those they have heard about: superovulation of donor with gonadotrophins; artificial insemination (AI); non-surgical removal of embryos; transfer of embryo to surrogate; and birth after embryo transfer. *Should biotechnology be used for rapid propagation of endangered species? Should cloning be used to replicate an organism?*

Acquisition and Development of Concepts

- Students research and debate the following statement: *If the most desirable domestic animals are able to parent an entire herd in each reproductive cycle, could this technique be applied to endangered species?* (In April 1990, Mary Alice, a rare Siberian tiger, was born as a result of *in vitro* fertilization technology.)
- Students interview a reproductive technologist using questions such as the following: *Should endangered species be preserved? At what cost? Who decides? Might this technology result in an uncontrolled monster?*
- Students research and debate the application of reproductive technologies in humans.

Application

- To evaluate the potential application of their findings, students might complete a risk/benefit analysis of the desirability of preserving endangered species by considering the following: safety, efficiency of practice, quality of life, and cost-effectiveness.

Suggestions for Instruction

Illustrative Example 2:

Demonstrate an understanding of the structure and function of genetic materials.

Much of the structure and function of every living organism is determined by genetic material. It may be important for a scientifically literate person to understand certain principles and fundamentals related to genetic material: what its make-up is, how humans are manipulating it, and why this major area of scientific and technological endeavour has implications for humans and planet Earth.

Activating Prior Knowledge

- Students brainstorm ideas about genetic material and discuss their preconceptions. They then assemble their ideas and show the interrelationships between these ideas on a Concept Web/Map, based on their current understanding. *How can the principles of genetics be applied to a case study such as the Human Genome Project completed in 2002?*

Acquisition and Development of Concepts

- Students extract DNA from onions or bacteria.
- Students research tools and techniques used to study genetics. Areas of research to consider include: the polymerase chain reaction (PCR) process, DNA fingerprinting, gene probes, recombinant DNA, cloning, genetic markers, and gene mapping.
- Students separate DNA using electrophoresis.

Application

- Students conduct a major research report on the Human Genome Project. Using a variety of print and electronic sources, they could consider the following areas: *How and why was the Human Genome Project conducted? What are the implications of decoding the complete human genome? What are potential career pathways that would enable a student to participate in the fruits of the Human Genome Project?*
- As a follow-up activity to the report, students debate the issue of whether society should support projects such as the Human Genome Project.

Illustrative Example 3:

Use the redox theory in a variety of contexts related to electrochemistry.

Students often use electrochemical applications in their everyday lives. By studying the design and function of various electrochemical technologies, students will better comprehend the relationship between science and technology with regard to the progress, evolution, and many uses of electrochemical cell technology. Other electrochemical processes and applications such as corrosion, corrosion protection, and electrolysis can also be studied within this context.

Activating Prior Knowledge

- Students discuss the different uses of batteries they have observed in daily life. Examples could include the use of batteries and electrochemical cells in cars, pacemakers, hearing aids, and electronic equipment. They could also mention differences in these batteries and cells, such as the difference between rechargeable and alkaline cells. *How can we increase the efficiency of electrochemical cells for everyday use?*

Acquisition and Development of Concepts

- Students manipulate and "dissect" several types of batteries and electrochemical cells. This would allow students to compare the internal structures and help them explain how each battery or electrochemical cell works in terms of electrochemical principles.
- Students design and build an electrochemical cell with a predicted voltage.
- Students test the electrochemical cell for the predicted voltage and suggest possible ways to increase the cell's efficiency.

Application

- Students work in teams to report on the use of electrochemical cells in a variety of contexts. The teams evaluate the appropriateness of these applications.
- Students work collaboratively to design and build an electrochemical cell to power a small, motor-driven device or a flashlight, and identify ways to maximize its efficiency.

Suggestions for Instruction

Illustrative Example 4:

Analyze and describe relationships between force and motion.

Force and motion affect our lives, whether we are driving a car or riding a roller coaster at an amusement park. Newton's laws of motion were revolutionary because they explained the behaviour of moving objects and systems on Earth and in the universe. Students should be provided with various situations involving examples of Newton's laws.

Activating Prior Knowledge

- Students request specifications from manufacturers on the design and function of safety devices such as seat belts, infant car seats, and airbags. Using these specifications, students discuss how the safety devices counteract the effect of the forces developed during a collision. *What physics principles govern the design of safety devices such as airbags?*

Acquisition and Development of Concepts

- Using the scenario of an automobile colliding with a wall, students identify the forces that would act on the car and its passengers, including different speeds at the time of the accident, the mass of the car, and the use or non-use of safety devices.
- Students identify the scientific principles and assumptions about human behaviour that underlie the design of safety devices.

Application

- Students consider whether it is a good idea for manufacturers to allow airbags to be disabled, or to increase the airbag activation speed from the current 30 km/h to 55 km/h, and lower the acceleration of airbag deployment from 300m/s to 210m/s.
- Students suggest ways to increase the levels of compliance for the use of safety devices such as seat belts, infant car seats, and airbags.
- Students design and construct a model roller coaster.

Illustrative Example 5:

Predict and explain interactions between waves and matter, using the characteristics of waves.

Understanding mechanical waves such as sound has artistic and aesthetic implications. For example, computers equipped with sound cards can produce musical sounds that are similar to the sounds produced by conventional musical instruments. The problem for software designers is to make the computer generate a realistic reproduction of the sound of a musical instrument. It is important to make students aware of the basic principles of sound and to encourage them to explore these phenomena through the use of concrete materials.

Activating Prior Knowledge

- Students use a variety of instruments to produce the note middle C. For example, students could listen to pure middle C and middle C sounds produced using computer .wav files. They then describe each sound produced. *How can you make a computer produce a middle C sound that is indistinguishable from that produced by a grand piano?*

Acquisition and Development of Concepts

- Students use terms such as *pitch*, *tone*, *frequency*, and *frequency mixing* to describe the similarities and differences between the sounds produced by the different instruments.
- Students use the computer sound card to produce different sounds through the process of mixing a middle-C frequency with other frequencies.
- Students use the oscilloscope to produce graphs of the sounds produced by different instruments.
- Students use the method of trial and error in the mixing process to make the computer produce the same graphs produced by the grand piano for middle C.
- Students examine the formation of "tidal" (seismic sea) waves.

Application

- Students create sound profiles for different instruments, using the appropriate technology.
- Students use the computer to create printouts of musical notation that correspond to sounds produced by the sound card.

General Learning Outcome D

Students will...

Explore, understand, and use scientific knowledge in a variety of contexts.

Specific Learning Outcome

SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

Suggestions for Instruction

Energy

The concept of energy provides a conceptual tool that brings together many understandings about natural phenomena, materials, and the process of change. Energy, whether transmitted or transformed, is the driving force of both movement and change. Students learn to describe energy in terms of its effects and, over time, develop a concept of energy as something inherent within materials and in the interactions between them (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Determine how cells use matter and energy to maintain the organization necessary for life.

A living thing is more than a set of chemical reactions or a physical machine. Much knowledge about living systems has been derived by studying cellular metabolism and the physical processes that occur within a cell. Students should have some appreciation for the complexity of life at the cellular and molecular levels of organization.

Activating Prior Knowledge

- Students discuss the four groups of fundamental biochemicals: carbohydrates, lipids, proteins, and nucleic acids. *What are the characteristics of the fundamental groups of biochemical molecules that are so important to life? How do cells get energy?*

Acquisition and Development of Concepts

- Students identify carbohydrates, lipids, and proteins through a variety of tests and indicators.
- Students use a calorimeter to measure the amount of energy (kcal) in foods.
- Students measure the metabolic rate of a unicellular organism and extract DNA.
- Students examine the process of metabolism, including the role of adenosine triphosphate (ATP).

Application

- Students conduct an interview with a biochemist to learn more about career opportunities in this field.
- Students research which micro-organisms are used to make certain biochemical products such as hormones and drugs.
- Students inquire into how various biochemical molecules are involved in cellular structures and processes.

Illustrative Example 2:

Predict and explain energy transfers in chemical reactions.

In Canada, many electrical power plants depend on the combustion of fuels such as coal, diesel, woodchips, and natural gas. As the production of energy and subsequent use of that energy costs money, there is a need to ensure an efficient process for producing and using energy. Students should be provided with opportunities to study the concept and issues of having heat to generate electricity.

Activating Prior Knowledge

- Students compare different ways of producing electricity in Canada. Various sources of energy, such as nuclear energy, hydroelectricity, wind energy, and others, will probably be mentioned, but the focus should be on the methods that use combustion reactions. *Which fuel is best to use in electric power plants?*

Suggestions for Instruction

Acquisition and Development of Concepts

- Students predict the amount of heat generated in a variety of combustion reactions using bond energies, heats of formation, and Hess's law. Their calculations leading to the predictions can be communicated graphically using potential energy diagrams.
- Students carry out experiments using basic calorimetry to measure the heat used or produced in a variety of chemical reactions. They then compare their experimental results with their predictions.

Application

- Students visit a power plant to gain a greater appreciation of the scope and complexity of the technology involved. They then relate their understanding to direct technological applications and potential careers.
- Students prepare a report recommending the use of a particular fuel for a power plant. In their recommendation, they take into account a comparison of the emission of greenhouse gases and other pollutants from the reactions. The report should also contain references to economic, scientific, technological, ecological, and ethical perspectives, as well as the issue of sustainability.

Illustrative Example 3:

Analyze and describe different means of energy transmission and transformation.

In their daily lives, humans are exposed to radiation from a variety of sources. In some situations, radiation (such as an X-ray) is beneficial, and in other situations, radiation (such as that from the sun) is potentially harmful. Students assess the risks and benefits of exposure to radiation from natural and artificial sources.

Activating Prior Knowledge

- Students perform an activity using readily available materials such as coins, coloured chips, and candies to demonstrate radioactive half-life, and draw a graph. This graph can then be related to decay curves, taken from reference sources, for other radioactive substances.
- Students work collaboratively to develop a plan for appropriate sampling procedures to determine the levels of radiation at home or at school. *How much radiation are humans exposed to in daily life, and what risks and benefits are involved?*

Acquisition and Development of Concepts

- Students can recognize, through the use of appropriate radiation detectors, that low-level radioactivity can occur in their environment (for example, smoke detectors use a small radioactive source, radon gas can seep into basements).
- Students use print and electronic resources to locate and summarize information such as common sources of radiation and half-lives of isotopes, and exposure levels of radiation per annum. They then determine their own radiation exposure levels.
- Students compare the causes of death from radiation with other causes of death, such as traffic accidents and smoking, and with deaths that occur in certain occupations and recreational activities.

Application

- Students complete a risk-benefit analysis of exposure to artificial sources of radiation or to sources used for biomedical diagnoses and treatments such as radioactive tracers and cobalt therapies.

Illustrative Example 4:

Analyze interactions within systems, using the laws of conservation of energy and momentum.

Bungee jumping has become popular with thrill seekers throughout the world. Designing bungee ropes and determining a safe height for the platform are important considerations in reducing risk. Students should be able to apply the conservation laws of energy and momentum when analyzing situations such as bungee jumping.

Suggestions for Instruction

Activating Prior Knowledge

- Students view, either directly or on video, the sport of bungee jumping and note the sequence of events during a jump. After viewing the video, they examine and note the properties of a bungee rope. *How can you redesign an existing bungee jump to accommodate jumpers of masses between 35 kg and 120 kg?*

Acquisition and Development of Concepts

- Students use the law of conservation of energy to determine the velocity a person would have at the end of the initial bungee jump.
- Students develop a design for a laboratory scale prototype of a bungee jump that can accommodate a range of masses. Students build and test the bungee jump prototype using a variety of masses, and make adjustments as necessary. Students compare theoretical data with data collected from prototype tests.

Application

- Students extrapolate findings from prototype tests to actual conditions, taking into consideration aspects such as the mass of the jumper, the height of the jump platform, free-fall distance, spring constant, potential and kinetic energies, using numerical and graphical modes of representation.
- Students identify tradeoffs in the design of a bungee jump (for example, thrill element versus safety precautions).

Illustrative Example 5:

Demonstrate an understanding of the nature and diversity of energy sources and matter in the universe.

Many of Earth's resources are nonrenewable. In recent years, humans have become more aware of the need to recover and use resources in a responsible way. Students should develop an understanding and appreciation of the finite nature of Earth's resources and how these resources should be used to meet both present needs and the needs of future generations.

Activating Prior Knowledge

- Through discussion or a brainstorming session, students indicate their understanding of the significance of mining or logging activities in a global context and the contribution of mining activities to the local, provincial, or national economy. *What types of information are necessary and what processes are used to make a decision about whether a specific mining activity should proceed?*

Acquisition and Development of Concepts

- Students analyze seismic data and drill-core sample data to determine the nature and size of a particular ore body. Students further analyze social, economic, and environmental factors to determine the economic viability or feasibility of developing the ore body, and to make and justify a decision.
- Students role-play or debate the question of developing a mineral resource that has been discovered in a protected area. As a group, students could reach a consensus as to whether or not the resource should be developed.

Application

- Students role-play as investors and apply their knowledge to the interpretation of a mining company prospectus.
- Students hold a town hall meeting to discuss this scenario: The local mine has just shut down and eliminated many jobs. A logging company would like to clear-cut a local forest.

APPENDICES

CONTENTS

APPENDIX 1: UNIT DEVELOPMENT IN SENIOR 3 CURRENT TOPICS IN THE SCIENCES

Unit Development

Senior 3 Current Topics in the Sciences is driven by learning outcomes and process. This design empowers teachers to plan appropriate learning experiences based on the nature of their students, school, and community. Teachers are encouraged to seek their own comfort level with the new curriculum, to share approaches and experiences with colleagues, and to use an integrated interdisciplinary focus to develop and extend student experiences and understandings in new ways. The thematic approach to integrated instruction will allow teachers to work closely together as they develop units that extend across disciplines (Willis).

Working with bigger ideas will allow a more in-depth inquiry. Organizing units around a problem or theme will generally present information in the context of real-world applications (Willis). Students will be presented with opportunities to uncover concepts from each of the sciences during the year in a substantial way and to make coherent connections between them.

> Science deals with major themes in which people are already interested or can readily be interested: life and living things, matter, the Universe, information, the "made-world." A primary reason, therefore, for teaching science to young people is to pass on to them some of this knowledge about the material world, simply because it is both interesting and important—and to convey the sense of excitement that scientific knowledge brings (Millar and Osborne 7).

Choosing a Current Topic

The flexibility of Senior 3 Current Topics in the Sciences allows teachers to design meaningful and engaging interdisciplinary units based on current scientific issues and developments. It is suggested that teachers develop three or four units for this course. The first step in the development of a unit is choosing a topic.

Choosing an effective topic is critical to the success of Senior 3 Current Topics in the Sciences. An engaging topic should have one or more of the following characteristics:

- is age appropriate and accessible to a diversity of learning styles, interests, and abilities
- is meaningful and engaging to students
- is of current societal and scientific significance
- incorporates a significant number of the student learning outcomes identified for this course
- connects a range of science disciplines
- is framed within the context of a question or problem
- provides opportunities for in-depth student-driven inquiry

- provides opportunities for both knowledge acquisition and skill development to arise naturally in context
- will result in a performance-based activity as a culminating experience

Teachers may decide to choose a topic from the suggestions listed below, develop a topic based on one of their own strengths or interests, or involve students in brainstorming a current scientific topic of interest that includes a significant treatment of scientific ideas, perspectives, content, and processes.

Possible Current Themes or Topics

- Are We Alone in the Universe?
- Biotechnology: The Good, the Bad, and the Unknown
- What in the World Is Climate Change?
- Cloning: What Can We Do and What Should We Do?
- Forensic Sciences: Crime Scene Investigation
- Where Will the Next Earthquake Occur?
- Energy Today and Tomorrow: Can We Avoid Large-Scale Blackouts?
- Environmental Interactions
- The Evolution of the Human Species: Where Did We Come From? Where Are We Going?
- Global Warming: Fact or Fiction?
- The Human Endeavour in Space
- Medical Technologies: What's New?
- Great Geological Controversies: Expanded Earth or Plate Tectonics?
- The "Snowball Earth": Has the Entire Planet Frozen over in the Past?
- Is the World Doing Enough to Reduce Pollution?
- Recycling: Is It Working?
- Science of Music: Why Do We Like It So Much?
- Sports Science: How Do Science and Technology Aid the Athlete?
- Stem-Cell Research: Ideas and Issues
- Technologies of the Future: What Was Predicted in 1950 and Where Are We Now?
- Transportation in the Future: Getting From A to B
- Water: Will We Ever Run Out?
- Causes and Consequences of Wildfires
- Human Population Cycles: Is There Room for Us All?

Senior 3 Current Topics in the Sciences welcomes and encourages the input of students in the choice of topics and in topic development. Teachers may choose to involve students in the development of a thematic unit. A brainstorming session with the class could allow students to generate topics of interest, from which a unit may be planned, or develop the essential understandings within the chosen unit.

The Forensic Sciences topic has been developed as a sample unit for teachers to consider for use in implementing this curriculum.

Planning a Unit

A unit plan evolves from a particular topic. A number of essential understandings within the area of interest could be generated, either by the teacher or with the help of students. *Essential understandings* are concepts, skills, or bodies of knowledge that are crucial for students to comprehend to develop an in-depth understanding of the topic. The essential understandings will likely determine the SLOs for GLO D (Essential Concepts).

The number of essential understandings generated will depend upon the topic, the amount of time allotted to the unit, and the interest of students. There may be essential understandings of particular interest to students that develop during the presentation of the unit, and teachers are encouraged to pursue these. While the size of a unit may vary (for example, from eight to 30 hours), teachers are encouraged to pursue a depth of treatment to essential understandings.

Teachers may choose to use development tools such as the Unit Development Using Essential Understandings Approach or the Unit Development Concept Map shown in the samples that follow. (Templates of these planning tools follow the samples.)

Unit Development
Using Essential Understandings Approach
Forensic Sciences: A Crime Scene Investigation Unit (Sample 1)

Current Topic: Forensic Sciences: Crime Scene Investigation

Essential Understanding: 1. Blood Analysis

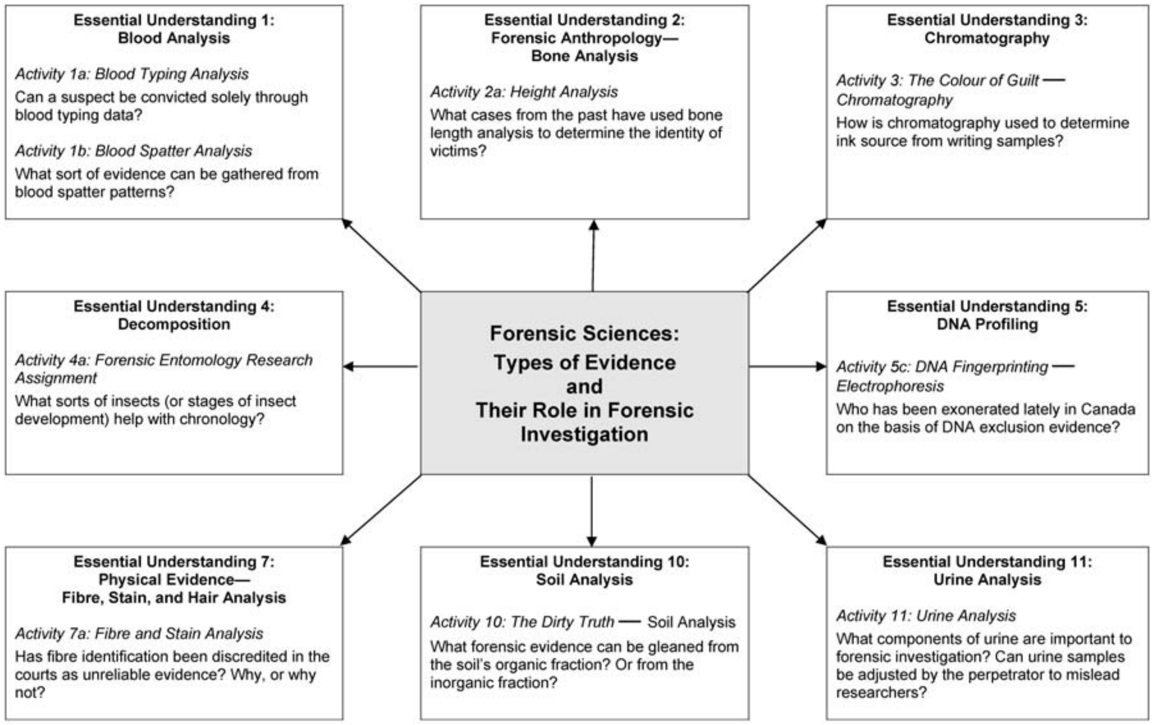
			SLO Tracking
Knowledge:		• There is a relationship between the distance a drop of blood falls and the diameter of its spatter. • There is a relationship between the angle and direction a drop of blood falls and its spatter pattern.	SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.
Skills:		• Measurement • Collaboration • Data Analysis	SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
Activities:		• Blood Spatter Analysis Lab	SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
Assessment:	Formative	• Blood Spatter Analysis Lab	SLO C1 SLO C4 SLO C5
	Summative	• Blood Spatter Analysis Lab Report	SLO A2 SLO C4 SLO D3

Unit Development
Using Essential Understandings Approach

Current Topic:			
Essential Understanding:			
			SLO Tracking
Knowledge:		•	
Skills:		•	
Activities:		•	
Assessment:	Formative	•	
	Summative	•	

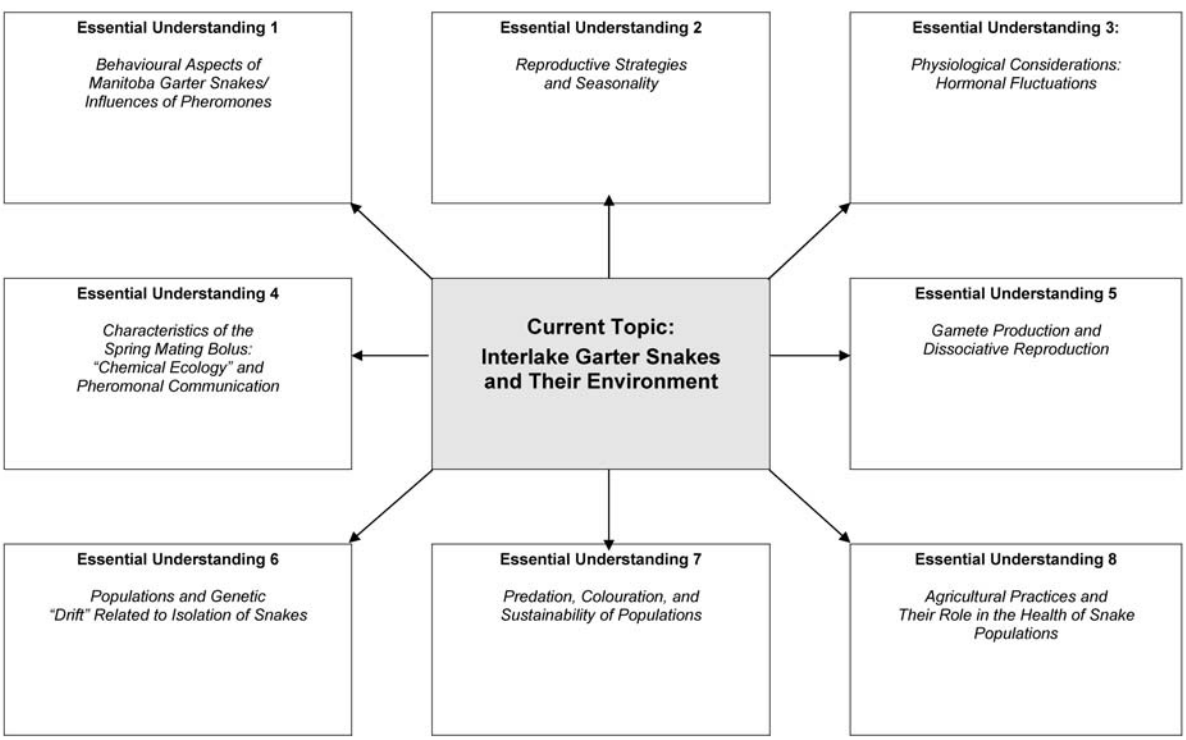
Unit Development Concept Map

Forensic Sciences: Types of Evidence and Their Role in Forensic Investigation (Sample 1)



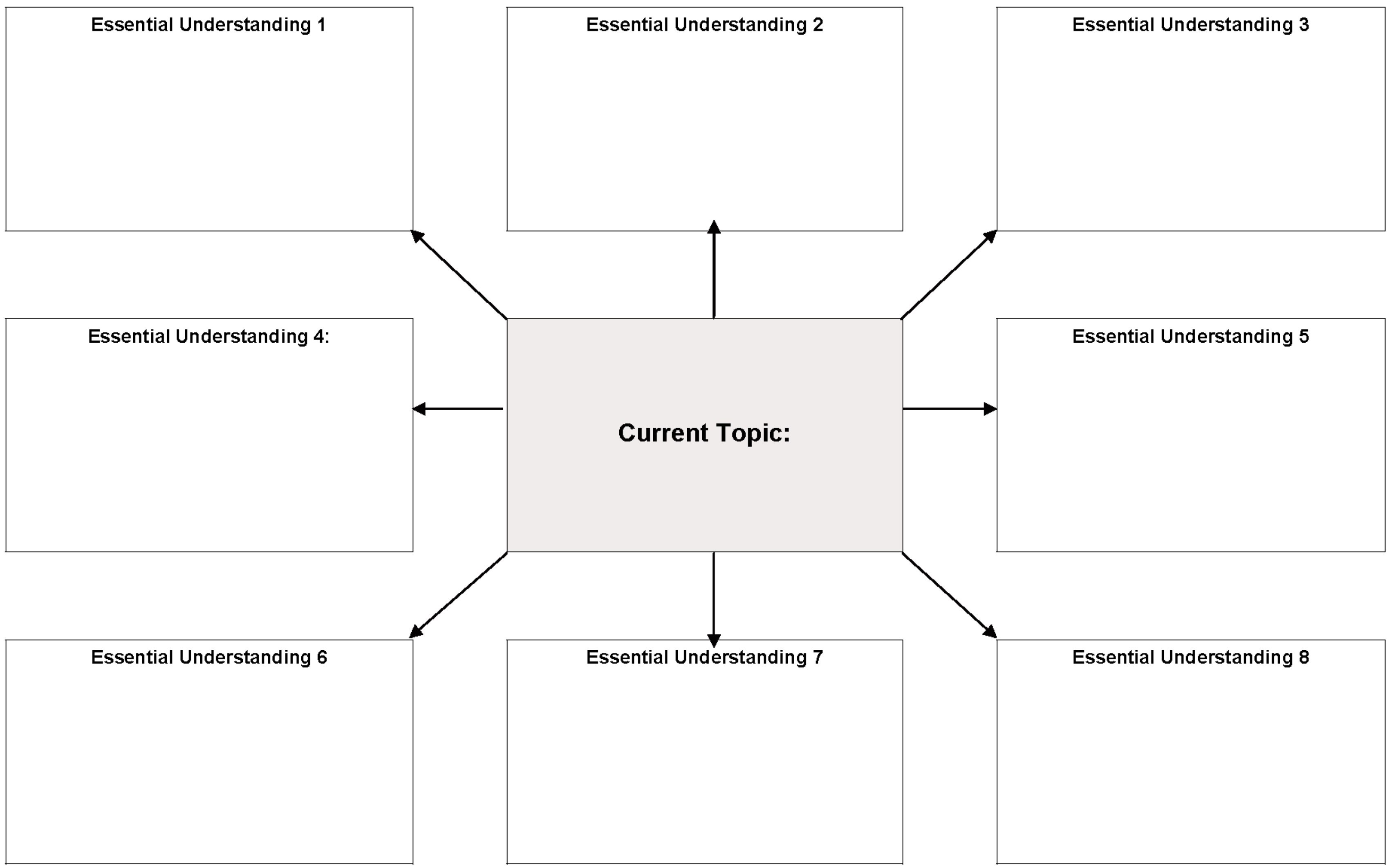
Unit Development Concept Map

Interlake Garter Snakes and Their Environment (Sample 2)



Note: There may be more or fewer than eight essential understandings. The arrows may serve to connect essential understandings to the topic.

Unit Development Concept Map



Note: There may be more or fewer than eight essential understandings. The arrows may serve to connect essential understandings to the topic.

Linking to Specific Learning Outcomes (SLOs)

After developing the initial unit plan, teachers can use an SLO Tracking Chart to link instructional strategies and student learning activities to specific learning outcomes (SLOs).

A single unit will not necessarily address all SLOs. The SLOs are cumulative in nature, and it is expected that a student will achieve all outcomes by the end of Senior 3 Current Topics in the Sciences.

An SLO Tracking Chart will assist teachers in determining whether each SLO has been addressed at least once during curriculum implementation. Many SLOs will be addressed more than once by virtue of the design of interdisciplinary units.

A sample SLO Tracking Chart for a set of learning activities for a Forensic Science unit is provided on the following pages. (A template of this chart follows the sample.)

Finding Learning Resources

After having developed a unit plan and tracking or auditing for SLOs, teachers may decide where and how to obtain information and ideas for learning activities. Teachers may gather information, or they may have students research and share.

Possible Sources of Information

- Textbooks
- Journals
- Interviews
- Teachers
- Internet
- Videos
- Community
- Students

Instructional Strategies

A variety of instructional approaches may be used, depending on the nature of the unit. For suggestions, see a discussion of Varied Instructional Approaches and Instructional Strategies in Section 2, as well as Appendices 2 to 6.

Assessment Strategies

Assessment strategies will vary, depending on the nature of the unit, the instructional strategies used, and the characteristics of the learners. For suggested assessment ideas, see Section 3 and Appendices 7 to 9.

SLO Tracking Chart

Forensic Sciences: A Crime Scene Investigation Unit (Sample 1)

Learning Outcomes	Forensic Sciences Activities								
	Blood Typing Analysis	Blood Spatter Analysis	Height Analysis	The Colour of Guilt—Chromatography	Forensic Entomology Research Assignment	DNA Fingerprinting—Electrophoresis	Fibre and Stain Analysis	The Dirty Truth—Soil Analysis	Urine Analysis
	1a.	1b.	2a.	3.	4a.	5c.	7a.	10.	11.
NATURE OF SCIENCE AND TECHNOLOGY **GLO A: Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.**									
SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.	•					•			
SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.		•					•		
SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.									
SLO A4: Recognize that science and technology interact and evolve, often advancing one another.	•					•			
SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.				•		•		•	
SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT **GLO B: Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.**									
SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.						•			
SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.							•		
SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.	•								•
SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.				•	•				
SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.								•	

(continued)

SLO Tracking Chart

Forensic Sciences: A Crime Scene Investigation Unit (Sample 1) (Continued)

Learning Outcomes	Forensic Sciences Activities								
	Blood Typing Analysis	Blood Spatter Analysis	Height Analysis	The Colour of Guilt—Chromatography	Forensic Entomology Research Assignment	DNA Fingerprinting—Electrophoresis	Fibre and Stain Analysis	The Dirty Truth—Soil Analysis	Urine Analysis
	1a.	1b.	2a.	3.	4a.	5c.	7a.	10.	11.
SCIENTIFIC AND TECHNOLOGICAL SKILLS AND ATTITUDES **GLO C: Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.**									
SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.	•		•				•		
SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.									
SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.						•			
SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.					•				•
SLO C5: Work cooperatively with others and value their ideas and contributions.		•	•			•			
ESSENTIAL CONCEPTS **GLO D: Explore, understand, and use scientific knowledge in a variety of contexts.**									
SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.	•		•			•	•	•	
SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.					•				•
SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.		•		•		•			
SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.					•				

Note: This chart is intended to highlight how student learning activities connect to the identified learning outcomes. It is not a comprehensive treatment of all activities in the sample Forensic Sciences unit.

SLO Tracking Chart

Learning Outcomes	Activities 1.	2.	3.	4.	5.	6.	7.	8.	
NATURE OF SCIENCE AND TECHNOLOGY **GLO A: Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.**									
SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.									
SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.									
SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.									
SLO A4: Recognize that science and technology interact and evolve, often advancing one another.									
SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.									
SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT **GLO B: Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.**									
SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.									
SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.									
SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.									
SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.									
SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.									

(continued)

SLO Tracking Chart *(continued)*									
Learning Outcomes	**Activities**								
	1.	2.	3.	4.	5.	6.	7.	8.	
SCIENTIFIC AND TECHNOLOGICAL SKILLS AND ATTITUDES **GLO C: Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.**									
SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.									
SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.									
SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.									
SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.									
SLO C5: Work cooperatively with others and value their ideas and contributions.									
ESSENTIAL CONCEPTS **GLO D: Explore, understand, and use scientific knowledge in a variety of contexts.**									
SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.									
SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.									
SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.									
SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.									

Note: This chart is intended to highlight how student learning activities connect to the identified learning outcomes.

Notes

APPENDIX 2: ACTIVATING PRIOR KNOWLEDGE

Using strategies to activate students' prior knowledge can be considered equivalent to preparing for a learning experience. The use of activating strategies can produce significant gains in learning potential by recognizing the importance of prior knowledge as the basis for familiarity with concepts, and by providing students with a context that argues strongly for new learning to occur.

Learning experiences that draw on students' prior knowledge act to

- assist students in relating new information (or skills) to what they already know and can do
- allow for the surfacing of misconceptions or naive conceptions that may impede learning
- allow teachers to make decisions to augment and strengthen students' knowledge before new information is engaged
- identify gaps in knowledge or skills that may exist
- stimulate interest and curiosity, or initiate an inquiry process that can provide a more personalized learning experience

The following learning strategies can be used in the science classroom to activate students' prior knowledge. Further information about these strategies can be found in other departmental publications, including the following:

- *Senior Years Science Teachers' Handbook: A Teaching Resource* (Manitoba Education and Training)—abbreviated as *SYSTH*
- *Senior 3 English Language Arts: A Foundation for Implementation* (Manitoba Education and Training)—abbreviated as *Senior 3 ELA*

Anticipation Guide (See *SYSTH* 9.20, 9.26, and *Senior 3 ELA* 4-336)

The teacher writes a number of statements to elicit a response to a topic. Students write an initial response to the topic and then discuss responses in small groups or in class. Students then listen to a lecture, watch a film, have a debate, or complete a reading. Afterwards, students write a response indicating why their opinions changed or were strengthened.

Brainstorming (See *SYSTH* 13.12)

Getting preliminary thoughts and ideas down in print or electronic form (e.g., in a Concept Map, web diagram, list) can bring thoughtful expressions of ideas into view for students. Some organization and clustering can be accomplished from an initial set of ideas. Many teachers are moving this task to students, and are using software aids (e.g., Inspiration®) as a way to help students organize ideas.

Clustering (See *Senior 3 ELA*, 4-288)

Clustering helps students to survey subjects and to see the connections between various associations. Students

- write a “nucleus word” or draw a central image in the centre of a sheet of paper
- record all the words and/or sketch all the images that come to mind around the nucleus
- circle each word as it is placed on the page and draw a line to the item to which it most closely relates
- examine the cluster for closely related words or images that could form the topic for a unit, or allow for discussion of a concept

Discrepant Event

A situation that is counter-intuitive and creates many excited questions and engages students in wondering “why.” For example, an instantaneous colour change that takes place when solutions are mixed (e.g., the classic “Nassau” or “clock reaction”) can help start a discussion of a topic or a process to be investigated.

Knowledge Chart (See *SYSTH* 9.9, 9.25)

A Knowledge Chart is similar to a KWL Chart.

KWL (Know–Want to Know–Learned) (See *SYSTH* 9.8, 9.24)

Using the KWL strategy and a three-column chart, students identify what they already know, what they want to know, and what they have learned in the lesson or unit. Concept Maps may be used to organize information within the columns, providing a summary and review of the information.

LINK (List–Inquire–Note–Know) (See *SYSTH* 9.18)

The teacher puts a concept or question on the board or overhead. Students write down their thoughts and ideas. In the class discussion that follows, students ask questions of each other while the teacher notes responses (e.g., on a Concept Map). Information is concealed and students write down what they remember (e.g., recreate Concept Map). Students then note what they have learned and what they need to know or learn.

Listen–Draw–Pair–Share (See *SYSTH* 9.15)

Students draw and label a diagram illustrating what they know about a topic. They share and compare their drawing with another student and then with the class. The teacher presents new information, such as an assigned reading, a lecture, or a film, and students alter, adapt, or redo their drawings. Students share their “before” and “after” drawings, discussing changes and differences.

Picture Puzzle

The teacher finds a picture (photograph, drawing, diagram) in which the subject is not obvious (such as a pollen grain or part of a meteorite). Students discuss what the picture could possibly represent.

Proposal Writing

For the purposes in this curriculum, proposal writing does not refer to grant-writing techniques. In the context of this curriculum, a *proposal* could reflect a response to an environmental problem (see English language arts, SLO 3.1.4). It can be particularly effective for student groups to submit a proposal for any large-scale project. A proposal assists in planning, and gives the teacher an idea of where strengths and weaknesses (or obstacles) could exist.

A proposal could include, but is not limited to, the following:

- outline of the main avenues of research
- resources to be used (e.g., print, online, expert witnesses)
- team membership and outline of responsibilities of each member
- steps to be taken in research and production of final report
- form of reporting that will take place (e.g., multimedia, oral, laboratory format report)
- suggested timelines for completion of project
- rubrics (or similar tools) that will assist students in self-assessment or peer review of the work

Rotational Cooperative Graffiti (See *SYSTH* 3.15)

A Rotational Cooperative Graffiti activity is often used as a group brainstorming strategy to expose and examine students' prior knowledge (under very limited time frames) of a topic, an idea, an issue, or a science concept. It is particularly entertaining and useful when the class is making a transition to a new component of the curriculum. One way to keep the enthusiasm elevated is to have groups rotate large sheets of paper upon which the ideas have been sketched out. The brainstormed ideas can exist as "paint splashes" (random positioning on the page), organized into lists, or drawn as pictures or cartoons. The strategy may be adapted as purposes require.

NOTES

APPENDIX 3: VOCABULARY BUILDING

To feel more successful at learning scientific vocabulary (often equated with learning a new language), students need a variety and a number of opportunities to engage scientific terminology. Some of this vocabulary is essential to operating comfortably within a science discipline (e.g., geology). To understand such particular vocabulary, students require knowledge that is both *definitional* (What does it mean?) and *contextual* (How is the term applied?).

The approach that is advocated in the *Senior Years Science Teachers' Handbook* (see *SYSTH*, Chapter 10: Building a Scientific Vocabulary) includes vocabulary-learning strategies at several levels:

- **Level 1 strategies** promote exposure to words using scientific dictionaries, word games, Word Cycle activities, suggested readings, and so on.
- **Level 2 strategies** require students to process words by creating their own definitions, creating Concept Maps using terms, using Compare and Contrast frames, Sort and Predict strategies, and so on.

The following learning strategies can be used in the science classroom to help students develop their vocabulary.

Sort and Predict (See *SYSTH* 10.13, 10.23)

Given approximately 20 foundation words, students develop four categories and group the words into these categories.

Three-Point Approach (See *SYSTH* 10.9, 10.22)

Students write the definition (in their own words), give a synonym or example, and draw a picture or a diagram of a word or concept.

Webs and Clusters (See *SYSTH* 10.11, 11.6)

Both Word Webs and Word Clusters are used to establish relationships between words by looking for similarities and differences. Word Webs show linkages between terms, with relationships described on a connecting line. Word Clusters show clusters of related terms grouped together.

NOTES

APPENDIX 4: RESEARCH

Learning through student-directed or student-initiated projects is known to be a highly effective pathway to promote individualized instruction or to make the best use of the diversity within the classroom. The inquiry approach advocated in Senior 3 Current Topics in the Sciences presupposes that students will have ample opportunity to develop and refine their research skills through gathering, filtering, processing, and evaluating scientific information.

The following learning strategies can be used in the science classroom to help students develop research skills and strategies.

Action Plan (See *Senior 3 ELA* 4-216 for Whole-Class Inquiry)

Students may submit action plans for group inquiries that include the following components.

Group Inquiry Action Plan					
Objectives	**Strategies**	**Responsibilities**	**Timelines**	**Results**	**Resources**

Concept Maps (See *SYSTH* 9.6, 11.7, 11.8, 11.11)

A Concept Map is intended to help students identify key vocabulary for a topic or identify the relationships between terms in a topic. The teacher may model this procedure by arranging pieces of paper with key terms to show the relationships or logical connections between them. Concept Maps may follow a category, a chain, or a hierarchy as an organizational strategy.

Email

The teacher can arrange links with schools, universities, or other research facilities in other parts of Canada or the world to have students carry out parallel research and to share and discuss data through email.

Interviews (See *Senior 3 ELA* 4-240, 4-226)

Students may analyze models of interviews and practise with peers before conducting interviews in the community. It may be useful to have a preliminary interview in which students introduce themselves, describe the topic and purpose, ask the interviewee what information or experience he or she is able to relate on the topic, explain how the interview will be conducted and how the information will be used, and discuss the time, length, and place of the interview.

Literature-Based Research Projects (See *SYSTH* 4.7)

A literature-based research approach can be applied to many STSE topics. A series of questions can direct students during their topic research. Students with competent literature research skills will be able to

- locate and analyze the validity of scientific information
- reduce unnecessary duplication of laboratory investigations
- recognize multiple perspectives from various interest groups
- determine how decisions are made at the local, provincial, and federal levels of government
- examine scientific, environmental, technological, societal, and economic sides of an issue

Teachers should model the five stages of effective research: planning, information retrieval or gathering, information processing, information sharing, and evaluation.

Plagiarism (Avoidance of) (See *Senior 3 ELA* 4-260)

Teachers use direct instruction to teach students the conventions for summarizing, paraphrasing, and quoting from research materials. To avoid plagiarism, students need opportunities for supervised practice in using secondary sources appropriately in their research.

Three Ways to Use Secondary Sources (Student Handout)

- **Summaries:** Summarize general information as you proceed with your research. General information consists of facts and concepts that are generally known and that appear in several sources. If you cannot judge whether information is generally known or is the property of one writer, you need to read several more sources. When you write your own text, synthesize the facts and concepts from these summaries in your own words. This information does not need to be referenced.
- **Paraphrases:** Paraphrase ideas and statements that belong to one writer, but that you do not wish to quote. To paraphrase, restate the ideas in a passage in your own words. You may need to use common words that appeared in the original, but do not repeat striking words or unique phrases that can be recognized as the style of the original writer. Reference the source of this material. It is considered good style to name the original writer in your paraphrase (e.g., Eldon Craig argues that the hog-nosed snake is a newcomer to Manitoba prairies.).
- **Quotations:** Quote striking or powerful lines that would lose their impact if they were paraphrased. Take care to quote lines accurately, and ensure that you do not lose or change their meaning by taking them out of their original context. Make arguments in your own words, and support them with a quotation rather than using quotations to make key arguments. Name the speaker or writer you are quoting, enclose the quoted material in quotation marks, and reference the source of the quotation.

Plagiarism (Avoidance of): Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) 4-260.

A form such as the following can help students distinguish between material cited directly and their own paraphrases, summaries, and comments.

Form for Recording Information	
Author's name: (last) ____________ (first) ____________ Title of source: ____________ Place of publication: ____________ Publisher: ____________ Year of publication: ____________	
Summaries: Briefly note the main ideas of the whole text.	**Paraphrases:** Write important and supporting information in your own words. Record the page number(s).
Comments: Record your own responses to questions about what you read.	**Direct Quotations:** Record only passages that you are very likely to quote in your final article. Record the page number(s).

Proposals (See *Senior 3 ELA* 4-221)

Students may submit proposals for major group projects. Depending on the project, the proposal may include the following categories:

- Purpose
- Audience
- Outline
- Resources
- Team Members and Their Responsibilities
- Steps in Research
- Risk Factors and Plans for Addressing Them
- Form for Reporting
- Timelines
- Progress Reports
- Criteria for Success

Reading Scientific Information (See *SYSTH*, Chapter 12)

Chapter 12 of *SYSTH* presents strategies to help students acquire the skills they need to comprehend science texts and scientific information accessed from multimedia sources. Students use interactive and collaborative strategies to understand and learn the content.

Good readers begin by skimming and analyzing a text and providing themselves with a structural and conceptual framework into which new information might fit. They then read for detail, with three levels of comprehension: literal understanding, interpretation, and application.

Students will be able to become better readers if teachers divide reading exercises into three sections:

- **Prereading:** Prereading strategies are intended to establish a purpose or focus, to activate prior knowledge, to emphasize new terms and vocabulary, or to provide familiarity with text features.
- **During-reading:** During-reading strategies are meant to promote collaboration, to help students recognize text structure, or to promote questioning and paraphrasing.
- **Post-reading:** Post-reading strategies are designed to teach students how to apply content by increasing comprehension and recall, connecting details to the big picture, making new connections, applying ideas, and transferring knowledge.

Various strategies are developed in *SYSTH*.

Surveys and Questionnaires (See *Senior 3 ELA* 4-226, Appendix C)

Students may submit a proposal for a survey or questionnaire in which they describe

- type of information they wish to gather
- type of survey they intend to implement
- target group and plan for random sampling
- how and when they will pilot the survey
- how and when they will administer the survey
- how they will analyze, interpret, and report data

Surveys are a useful tool for collecting information, particularly on timely, community-based inquiry topics. The following should be considered when designing and conducting a survey:

- Purpose
- Appropriateness
- Practicality
- Clarity
- Reliability
- Target Group
- Sample
- Random Selection

Types of surveys include fixed response questions (multiple choice, agree-disagree, checklists), rating scales (numerical, categorical), open-ended, and phenomenological (extended interview). Students may choose to pilot their survey before administering it.

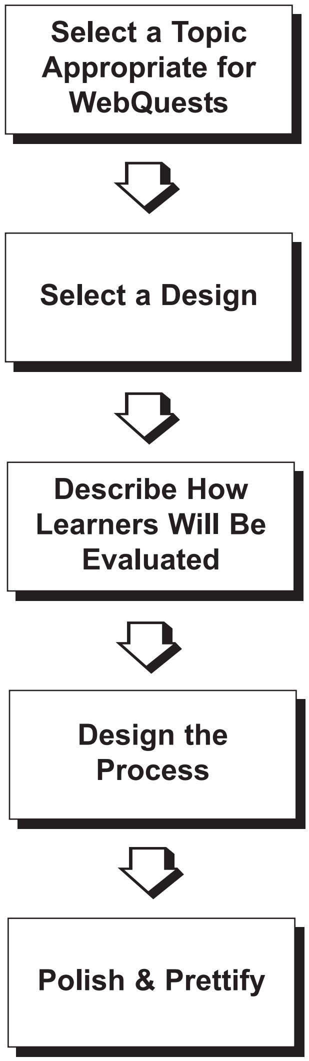
WebQuest

A WebQuest is an inquiry-oriented activity in which most or all of the information used by learners is drawn from the Web. WebQuests are designed to make efficient use of time, to focus on using information rather than looking for it, and to support learners' thinking at the levels of analysis, synthesis, and evaluation.

A basic WebQuest design includes an introduction, a task, a set of information sources needed to complete the task (not all sources need to be web-based), a description of the process in clear steps, guidance (such as guiding questions, timelines, Concept Maps), and a conclusion. WebQuest design information, templates, and samples may be obtained at *The WebQuest Page:* <http://webquest.sdsu.edu/>

The following flow chart shows possible stages involved in the development of a WebQuest.

The WebQuest Design Process



0. Do you really need to create a WebQuest from scratch?
Read **http://webquest.sdsu.edu/adapting/index.html**
to learn about adapting existing WebQuests.

1. Read:
http://webquest.sdsu.edu/project-selection.html
Pick a topic that requires understanding, uses the web well, fits curriculum standards, and has been difficult to teach well.

2. Study:
http://webquest.sdsu.edu/designpatterns/all.htm
Select a design that will fit your topic. Download the student and teacher templates for the design you chose. Open them up in your favorite web editor (Dreamweaver, Composer, FrontPage, etc.).

3. Write up the **Task** in the student template and the **Standards** and **Learners** in the teacher template.

4. Read:
http://webquest.sdsu.edu/rubrics/weblessons.htm
and
http://webquest.sdsu.edu/rubrics/rubrics.html

Complete the **Evaluation** section in the student template. Duplicate it in the teacher template and add any extra information needed by teachers.

5. Read:
http://webquest.sdsu.edu/searching/fournets.htm
and
http://webquest.sdsu.edu/searching/specialized.html

Flesh out the **Process** section by finding a focused set of resources to provide the information needed by learners.

If you have any doubts about the legitimacy of a site, check it out with Fagan's URLInfo tool.
http://www.faganfinder.com/urlinfo/

Scaffold where needed with Process Guides.
http://webquest.sdsu.edu/processguides/

Check yourself:
http://webquest.sdsu.edu/processchecker.html

6. Complete the **Introduction, Conclusion** and **Credits** section and all other parts of the teacher template. Add graphics where appropriate.

Read:
http://webquest.sdsu.edu/finepoints/

Have someone else evaluate your draft:
http://webquest.sdsu.edu/webquestrubric.html

The process isn't always as linear as this, of course. As you work your way through the steps, you may need to go back and modify the work done in previous steps. By the time you get to the bottom, you're done! The most difficult part is choosing a design and task. The most time-consuming part is designing the process.

The WebQuest Design Process: Reproduced from *The WebQuest Page*, Educational Technology Department, San Diego State University: <http://webquest.sdsu.edu/designsteps/index.html>.

APPENDIX 5: ANALYSIS

The strategies used for *analysis* are primarily directed at developing students' facility with "pulling apart" ideas and issues, drawing comparisons, employing critical thinking skills, and contrasting several sides of an issue. The *Senior Years Science Teachers' Handbook* suggests a host of opportunities for students to be involved in analytical techniques (see *SYSTH*, Chapter 10: Building a Scientific Vocabulary and Chapter 11: Developing Scientific Concepts Using Graphic Displays).

The following learning strategies can be used in the science classroom to assist students in developing skills in analysis.

Article Analysis Frames (See *SYSTH* 11.30)

The Article Analysis Frame focuses students' questions before and during reading. Students decide whether the article deals with facts or with issues, and then choose the appropriate frame.

- **Issue-Based Article Analysis** (See *SYSTH* 11.40 for Template)
  Students use the Issue-Based Article Analysis frame when reading articles that present a certain point of view about an issue under dispute.
- **Fact-Based Article Analysis** (See *SYSTH* 11.41 for Template)
  Students use the Fact-Based Article Analysis frame when reading articles that are informative but do not raise any concerns.

Case Studies (See *SYSTH* 4.14-4.17)

Case studies provide students with opportunities to analyze and interpret scientific data, their interaction with technology, and their impact on society and the environment. Case studies are often used in place of laboratory investigations, where conventional laboratory work is difficult. Current research information and data looking at the various sides of the issue may be presented and analyzed. Decision-making based discussion may then take place.

Concept Relationship Frame (See *SYSTH* 11.20)

A Concept Relationship Frame is designed to help students examine particular associations between concepts, such as cause/effect, problem/solution, either/or, or compare/contrast. A sample template follows.

Concept Relationship Frame (Comparing Science and Technology)

	Scientific Question	Technological Problem
Context		
Goal(s)		
Method(s)		
Product(s)		
Value(s)		

Looking for Differences

Students compare two different presentations of similar information (such as articles, videos, posters). They observe the various techniques and devices and assess the effectiveness of each.

Textbook Assessment (See *Senior 3 ELA* 4-142)

Having students assess textbooks helps them develop their critical thinking, as well as their awareness of the organization of the text. As students analyze a group of similar texts, they observe the following:

- Are the graphs, diagrams, and tables clearly captioned? Do they appear on the same page as the text that supports them?
- How is new vocabulary presented?
- Where are the questions? Are they clear and well-written? Do they require students to synthesize, criticize, and/or apply information from the text?
- Do the authors illustrate ideas with real-life examples, photographs, and illustrations to which all students can relate?
- Is the reading level of the text appropriate for the intended audience?
- Is the text engaging to the intended audience?

APPENDIX 6: SCIENTIFIC COMMUNICATION

One of the primary skill thrusts of Senior 3 Current Topics in the Sciences is that of providing many opportunities for *scientific communication*. Some of these instances will mimic the behaviours, traditions, and organizational aspects of a *scientific community*. Others are intended to be more authentic and directly promote student-centred development of skills related to the unique demands of communicating scientific ideas and results effectively.

The following strategies can be used in the science classroom to communicate scientific information.

Audience (Adaptation for)

Students adapt information, such as a paragraph in a textbook, for a different audience.

Booklet, Brochure, Pamphlet

Students may present information they have obtained through research or investigation in the form of a booklet, brochure, or pamphlet. This medium is most effective if the information to be represented involves a series of individual steps or points, and includes diagrams or pictures. Students involved in graphic arts may consider this an effective means of communication.

Cartoons

An individual scientific concept, rule (such as a safety rule), or law may be effectively communicated by a cartoon, an illustration, or a series of pictures.

Charts

Information or results that show related tendencies or patterns may be presented best in an organized chart. A flow chart may allow the steps of a process to become more apparent.

Concept Overview Frame (See *SYSTH* 11.25, 11.37)

After studying a concept, students may fill out a Concept Overview Frame. This will allow them to summarize what they have learned.

Data Table

Data measured during the course of an investigation are often best organized in a data table. The data table should have a title, labelled rows and columns, and the correct units. It may include several trials and the average values, as well as the equations used (in variable form). The data table should be prepared before the experiment begins.

Debates (See *SYSTH* 4.19)

Debates are effective in presenting divergent opinions and attitudes related to STSE issues. The debate usually draws on students' own positions on science-related social issues. Pro and con formats can be used to illustrate the main points and to create a dialectic within the debate. While the scenario is often make-believe, the debate provides a forum for personal commentary. Because students often hold debated opinions with greater personal conviction, the debate must be structured in a manner in which sensitivity to various points of view is accepted, if not agreed upon.

Suggested Organization of Debates

1. Select two small balanced groups of students who support divergent and opposing views on a science-related social issue.
2. Provide or have students research background information.
3. Students on each side of the issue prepare and coordinate their evidence to avoid redundant arguments.
4. Select a moderator to monitor time and response to questions.
5. Remind students to listen to and respect divergent points of view. Discourage the notion that only one viewpoint is correct.

Demonstrations

Demonstration of a technique or a procedure is an effective way to communicate an understanding of the process.

Diagrams

A visual communication is often more effective than a written description. Labelled diagrams may be useful for showing equipment setups, cycles, and so on.

Dramatic Presentations

Many creative students enjoy dramatizing the information to be presented (such as the history of science) in the form of a skit, a role-play, a play, or a movie. Students must be prepared to research appropriate materials before constructing the dramatic presentation, as this process may be time-consuming. Care must be taken to ensure that students concentrate on the scientific concepts and knowledge, not solely on the dramatization.

Graphing

Representing data in graphical form helps make the relationship between variables more obvious.

- When planning the graph, students need to consider scale. They determine the maximum values for both axes and make the scale accordingly.
- Students label both the vertical and horizontal axes with the factors being graphed and indicate the units being used.
- If the points indicate a straight line, students may use a straight edge. If a line of best fit is required and calculated on the calculator, students need to represent their calculations accurately.
- In a sentence or two below the graph or within the analysis, students explain the implications or main point revealed by the representation.

Historical Perspectives

Students communicate information from the perspective of an individual (scientist, layperson) in another time period. They may choose to write an article critiquing an idea that was controversial in its time (such as smallpox vaccination or the Earth's orbit). Students research information and reflect on their response. Variations include responding from a different age or cultural perspective.

Inquiry or Research Paper Handbook (See *Senior 3 ELA* 4-270)

Working in groups, students produce a handbook outlining the various stages, processes, and strategies of the inquiry or research process. This handbook is then available as a reference during the course of study, and may be modified or supplemented as required.

Journals

A scientific journal is an effective way for students to record thoughts and ideas during the progression of learning. Teachers may ask students to reflect on and respond to particular questions, such as noting their thoughts on a current issue in the newspaper. Alternatively, students may record their thoughts and feelings as they read a certain piece of scientific literature.

Learning Logs

Students keep an inquiry or research log throughout their inquiry or research project. In this log, students may collect various artifacts representing stages in the research process, as well as record anecdotes of the experience.

Models

Students may create two- or thee-dimensional models of a particular concept, theory, or idea. This may involve the use of materials such as papier mâché or modelling clay.

Multimedia Presentations

Students may choose to communicate their understanding through the use of PowerPoint software, a video, or other types of electronic media.

Newspaper Articles

By writing as reporters from a particular period of a society's history, students may see different perspectives of a scientific issue or idea.

Oral Presentations

Gaining ease, composure, and a public presence while speaking to an audience are skills developed over many years of schooling and extracurricular activity. At certain points in a student's experience, some growth is encouraged in the arena of public oracy. When oral presentations are compulsory for students, teachers are encouraged to exercise caution and discretion. Focusing on these situations as celebrations of learning that students have mastered promotes confidence and success in addressing peers publicly.

Posters

The poster session at scientific meetings has long been a standard in scientific communication, and provides an alternative venue for the presentation of new results to the large-scale public lecture that is not able to engage at a personal level. Senior 3 Current Topics in the Sciences is uniquely suited to the demonstration of student work in the form of poster presentations. In a poster presentation, there is ample opportunity to "get close" to the creators of the work, ask questions, point out interesting facets of their work, and offer suggestions for continued efforts.

Presentation Software

Students may use presentation software, such as PowerPoint, to present their information. Students must determine which sounds and images are suitable, and enhance communication, as well as learn how to use the program's elements to unify their presentation.

RAFTS (Role-Audience-Format-Topic-Strong Verb) (See *SYSTH* 13.23 for Format)

The RAFTS writing assignment is a portfolio strategy designed to produce creative and imaginative writing pieces in science. Through these assignments, students can

- see alternative perspectives on a science topic or issue
- uncover divergent applications of science concepts
- make connections between their world of experience and their science learning (e.g., metaphorical stories)

Recommendation Report (See *Senior 3 ELA* 4-270)

Students write a short reflection on the implications of their inquiry findings. In their reflections, students may wish to

- identify subsequent inquiry topics that might grow out of the one they have researched
- suggest how the information gathered in the inquiry could be applied
- recommend action that should be taken to solve a problem
- explore how public awareness could be raised about an issue
- describe how they will think or act differently because of the inquiry

Role-Playing (See *SYSTH* 4.18)

Role-playing scenarios teach selected social processes that govern relations, such as negotiating, bargaining, compromise, and sensitivity. Ultimately, students would use these skills as they move from vision to action in dealing with STSE issues. Role-playing often provides an avenue for presenting biased opinions, which may or may not agree with the opinions of students. Most importantly, it introduces divergent points of view and allows students to analyze and respond, thereby giving them an opportunity to gain an appreciation for why individuals hold divergent points of view. Ideally, the role-playing scenario fosters critical-thinking skills while promoting tolerance of other world views. All simulations have rules that govern human interaction. Regardless of the roles assumed, certain behaviours should be promoted, while others should not be allowed.

Roundtable

A roundtable discussion should engage all students in open scientific discussion. The discussion may be initiated by concepts outlined in a scientific article. The opening question should engage all participants and be based on the text of the article. Although it is not necessary, the teacher may ask *each* student to respond briefly to the first question to “break the ice.” (Examples of opening questions are: “What is the most important idea in this text? Why?” and “Do you think this text is scientifically valid? Why?”) The core question may be changed during the roundtable discussion to clarify a response or to refocus the group. This question should be focused more directly on the text. (For example: “Why did the scientists use [this animal, technique, equipment]? or “Explain what the author meant by the word ______ in Paragraph #4.”) This question should encourage students to examine how their thinking has changed during the course of the roundtable discussion. The teacher may want to ask questions (such as “How have your answers to the opening question changed?” or “How does the topic relate to your lives?” or “What could be done next?” or “What would you change?”). These questions should not solicit answers to which everyone would agree.

- **Role of Teacher:** The teacher’s role is to facilitate, not validate. Try not to make any response, whether with a facial expression, nod, or frown, that would indicate a right or wrong answer. Ask questions that provoke and take thought to a new level. Remind students to back up thoughts with facts from the document. An idea might be to diagram the seating arrangement, “web” the responses, and add a word or phrase beside the name of the speaker. This strategy can help
  - —identify who speaks and how often
  - —provide cues to additional questions
  - —keep the teacher from physically affirming responses

  If one student appears to monopolize the roundtable, each student may be issued five chips. Each time the student speaks, he or she gives up a chip. Therefore, the student has five opportunities to speak.

- **Role of Student:** Student participation (both speaking and listening) is mandatory. Students need to be courteous and respectful of classmates. They speak without raising their hands, talk to each other, and address the person they are speaking to by name. A roundtable is a way for students to communicate what they think about the document, not what they feel. They should always refer to the text.

Scientific Paper (See *SYSTH* 14.13 for Format)

At the Senior Years, exposure to the writing of a technical, scientific "paper" is of utmost importance, but should be treated in an introductory manner. Many students face the reading (or writing) of the scientific paper rather suddenly at the post-secondary level of study, and are ill-prepared for it. In reality, particular scientific journals have their own preferences as to writing style, format, and so on. No single format or referencing style should be advocated exclusively, but exposure to a few examples is helpful (for instance, using an American Psychological Association [APA] style of referencing versus numerical endnotes).

In the *Senior Years Science Teachers' Handbook*, teachers are offered some standard, normative samples of the laboratory report format and the scientific paper format (see *SYSTH*, Chapter 14: Technical Writing in Science, 14.11 to 14.15). Keep in mind that one of the chief purposes of the classical scientific paper is to announce the results of research related to *new contributions* in a field. Consequently, its role and purposes are distinct from that of a research or position paper.

Storyboard

Students could create storyboards to show the development of a scientific concept or theory. Discussion may then centre on the suggestion: "What might have happened if the order of occurrence had been changed?" (Changing chronology.)

Web Page Creation (See *Senior 3 ELA* 4-168)

Stages of creating a website may include

- surveying other websites on the same subject
- compiling a list of criteria for an effective website on the chosen subject
- writing a proposal for the website, describing its intended audience and purpose
- using a flow chart for constructing a personal website or contributing to the school's website

Word Cycle, Word Glossary (See *SYSTH* 10.21)

A Word Cycle is considered a Level 1 strategy in building a scientific vocabulary (for instance, see *SYSTH*, Chapter 10: Building a Scientific Vocabulary). The value in using a Word Cycle comes from taking a broad concept such as an ecosystem, providing a list of terms that could be related to that concept, and then asking students to link these words coherently. Students then learn how terminologies are related, broaden meaning of terms, and promote collaboration. Teachers are encouraged to use Word Cycle activities with their students in a cooperative manner (e.g., pairings).

A Word Glossary, steadily accumulated over time, is a useful way for students to organize the large number of terms that science topics bring forth. Pay close attention to the repetitive use of prefixes (e.g., neuro-) and suffixes (e.g., -logical) in scientific parlance.

Written Lab Report (See *SYSTH* 11.38, 11.39, 14.12)

There are a variety of formats for lab reports within a common framework. A lab report may contain the following information:

- **Abstract/Introduction:** A condensed version of the entire paper, placed at the beginning of the report. The material in the abstract is written in the same order as it appears within the paper, and should include a sentence or two summarizing the highlights from each section. The abstract is written once the paper is complete.
- **Purpose/Objective/Problem:** A brief statement of the purpose or objective of the experiment.
- **Background Information:** Information drawn from research.
- **Pre-Lab Theory:** The posing of a theoretical solution to the problem before the experimental procedure. It may involve a conceptual explanation and mathematical calculations.
- **Hypothesis:** Contrary to the persistent myth, a hypothesis is not an "educated guess" about what will happen. A statement such as "cigarette smoking causes cancer" is a hypothesis because it is a statement of suggested behaviour in the material world that is *testable* by scientific means. A hypothesis intends to make a *contingent claim* based on prior accepted models about how the world works. The claim, then, is subject to testing over and over again. It is the task of the investigation procedure either to support or to nullify the hypothesis statement.
- **Variables:** For the purposes of this curriculum, anything that comes in different types or different amounts and could possibly enter into an investigation. The simplest sort of relationship to examine is that between two variables (e.g., a person's height and arm span). It is not always a simple task, however, to *control* all the variables that may confound a scientific investigation.
- **Materials:** A list of the materials to be used in the experiment and a labelled diagram of equipment set-up, if applicable.
- **Procedure:** Written step-by-step directions for performing the experiment and regulating the controls, and a summary of the steps taken, so that someone who has not performed this lab would be able to repeat it. If a mixture is heated, the temperature should be given. Any modifications to the procedure should be noted. When following a procedure from a secondary source, reference should be given for the source.
- **Results:** Include drawings, measurements, averages (if applicable), observations, data tables, calculations, and graphs.
- **Observations:** Qualitative interpretations of what is occurring during the course of an experiment. Examples include colour changes, odour, formation of a precipitate, release of gas, temperature differences, pressure changes, or changes in solubility.
- **Quantitative Data:** Measurements taken directly from laboratory instruments. Data must be collected with care during the experiment, properly identified, and the correct numerical values and units used. Suspected faulty data must be presented and explained in the conclusions if not used in the analysis.
- **Sample Problems:** Show the conversion of data into results. Calculations should be properly labelled, with the accuracy and precision of the instruments taken into consideration, and the correct number of significant figures used.

- **Analysis:** An important part of the report that demonstrates an understanding of the experiment. It contains an interpretation or explanation of results, indicating their significance, how accurate the original hypothesis was, sources of error and their effect on results. The analysis also indicates ways to improve the experiment, including modifying the procedure, the equipment, the variables, and so on. The analysis can relate results to the real world and may describe a follow-up or auxiliary experiment.
- **Conclusions:** A summary of results and whether the purpose of the experiment has been achieved. Readers often read the conclusion first.

Zines (See *Senior 3 ELA* 4-166)

Zines or fanzines are science fiction magazines. Zines usually treat a particular theme. Components may include

- cartoon
- collage
- editorial
- interview
- memoir
- poem
- review
- survey results

APPENDIX 7: ASSESSMENT

For the purpose of this curriculum, assessment is the systematic process of gathering information about what a student knows, is able to do, and is currently *learning to do*. Science education today, therefore, demands a broad range and variety of assessment tools to gauge student learning. An inclusive classroom will encourage, whenever possible, assessment opportunities that provide *all students* with the chance to demonstrate what they know *most of the time*.

This Appendix provides an overview of various assessment perspectives intended to promote fair assessment and evaluation and increase students' role and responsibility in their own ongoing assessment. Some actual assessment instruments that are proving to be effective in today's classrooms are also included.

Teachers are encouraged to review the *Senior Years Science Teachers' Handbook* (see *SYSTH,* Chapter 15: Assessing and Evaluating Science Learning).

Concept Relationship Frame (See *SYSTH* 11.20, 11.25, 11.35)

This differentiated instruction technique is designed to help students examine particular, detailed associations between two concepts (i.e., cause/effect, problem/solution, either/or, compare/contrast). The aim is to avoid superficial analysis by probing for deeper associations. Chapter 11: Developing Science Concepts Using Graphic Displays in *SYSTH* demonstrates how the Concept Relationship Frame can be used effectively.

Developing Assessment Rubrics in Science (See Appendix 8)

Appendix 8 outlines various ways in which students can be engaged with their teachers in the development of assessment rubrics. It addresses questions such as the following:

- What are assessment rubrics?
- Why do teachers use assessment rubrics?
- How can assessment rubrics enhance instruction?
- What are some sources of rubrics? Sources include classroom-developed, teacher-developed, and externally developed rubrics.

Journal Writing and Assessment (See *SYSTH* 13.21)

Journal writing is a *writing to learn* strategy that engenders mixed feelings among students. Part of the "uncertainty" comes from the inability to be passive about one's learning if one is asked to comment upon it, write carefully about it, or be reflective about it. Journals should have an *informal*, familiar tone but should not be quaint or dismissive. Journal entries can be simple and short, vary in frequency, be structured to a particular format, or be free-form. It is valuable to consider how best to use journalling in the science classroom, but experience shows that overuse defeats the purposes of the journal. For instance, if journalling has little or no assessment/evaluation potential toward a student's grade, or does not provide a means of teacher feedback, it is difficult to sustain a successful experience.

Establishing a dialogue with students is an important element of formative assessment. Teachers may respond to students' journal entries, extending student thinking through comments and questions. In assessing journal entries, teachers may look for different interpretations and consideration of different perspectives, analysis, and growth.

Laboratory Report Assessment (See Appendix 9)

The Lab Report Assessment rubric (found in Appendix 9) is designed for both self-assessment and teacher assessment, and includes criteria such as the following:

- Formulates Testable Questions
- Formulates a Prediction and/or Hypothesis
- Creates a Plan
- Conducts a Fair Test and Records Observations
- Interprets and Evaluates Results
- Draws a Conclusion
- Makes Connections

Observation Checklist: Scientific Inquiry—Conducting a Fair Test (See Appendix 9)

This rubric (found in Appendix 9) is designed with five performance criteria, and can be used for an entire class list. The emphasis is on gathering information over time observationally. The criteria include the following:

- Demonstrating Safe Work Habits
- Ensuring Accuracy and Reliability
- Observing and Recording
- Following a Plan
- Showing Evidence of Perseverance and/or Confidence

Peer Assessment (See *Senior 3 ELA* 4-307)

Peer conferences could be organized to allow peers to act as problem solvers who offer concrete suggestions. The teacher may choose to provide students with questions and prompts. For instance, if students are editing a research paper, the peer assessment may include the following questions:

- Does the text contain enough information?
  - Pose questions that are not answered.
  - Mark passages that require more information.
- Is the text well organized?
  - Use arrows to show suggested reordering of paragraphs.
  - Mark places where a transition is required.

- Is the text clear?
  - Mark passages that are clear.
  - Mark words or phrases that need to be explained or defined.
  - Mark passages that need charts, graphs, diagrams, or examples.
- Is the information communicated in an interesting way?
  - Mark the least and most interesting sections.
- Are the sources referenced?
  - Mark un-referenced information.
  - Suggest other sources that may be used.

Peer/Self-Assessment Sheet for Poster Project (See Appendix 9)

This rubric (found in Appendix 9) is designed as a peer/self-assessment of a poster project in relation to an STSE-related inquiry. The rubric includes opportunities to assess the physical characteristics of the poster (e.g., clear organization and appearance), in addition to the science content aspects of the poster.

Performance Assessment

Performance assessment may take the form of

- demonstrating a lab technique (e.g., lighting a Bunsen burner, using a balance, focusing a microscope)
- demonstrating a safety procedure
- interpreting Workplace Hazardous Materials Information System (WHMIS) labels
- identifying an unknown

Portfolios (See *Senior 3 ELA* 4-180)

Portfolio items that allow students to demonstrate attainment of specific learning outcomes include

- inquiry logs
- project proposals
- webs and maps
- samples of notes
- reports on primary research
- reflective pieces

Reading Scientific Information (Concept Map Evaluation) (See *SYSTH* 12.15 to 12.19)

Chapter 12: Reading Scientific Information of *SYSTH* suggests techniques for comprehending science texts. It includes examples of how students could take notes from text in the manner of a detailed Concept Map organizer (see 12.16) and how this strategy can connect to *reading for meaning*. Once teachers have effectively modelled the techniques and students have had ample time to practise with scientific reading skills and note-taking, some criteria can be established that can be used in evaluation (see 12.19).

References

Students hand in a preliminary list of references as part of their research paper proposal.

Rubric for Assessment of Class Presentation (See Appendix 9)

This rubric (found in Appendix 9) is designed with four performance levels, and includes assessment criteria such as the following:

- Content
- Interest and Enthusiasm
- Clarity and Organization of Materials
- Use of Visual Aids

Rubric for Assessment of Research Project (See Appendix 9)

This rubric (found in Appendix 9) is designed with four performance levels, and includes criteria such as the following:

- Sources of Information
- Information Collected
- Organization of Material
- Presentation of Material

Rubric for Assessment of Scientific Inquiry (See Appendix 9)

This rubric (found in Appendix 9) is designed for guidance of student assessment in relation to the performance of *scientific inquiry tasks.* The rubric is not intended to be comprehensive, but seeks to provide some project-management parameters for teachers who are observing their students' initial attempts at sophisticated investigation work.

The rubric is designed around four levels of competency, as continua, and includes criteria in the following areas:

- Development of a Position Statement (Proto-Abstract)
- Objective/Purpose/Testable Question
- Procedure (design of the investigation)
- Data Collection
- Analysis and Interpretation of Results
- Application/Discussion of Scientific Results and Concepts
- Independence Factors (measuring degree of reliance upon outside assistance)

Self-Assessment

Self-assessment by students is integral to the overall assessment of learning. To assess their own work, however, students require some detailed advance knowledge (e.g., criteria) of what the expectations are. More advanced learners in this self-reflection process can then participate in setting criteria with their teacher(s). Teachers are encouraged to model self-assessment before expecting students to assess themselves.

Word Cycle (See *SYSTH* 10.6 to 10.8, 10.21)

A Word Cycle is considered a Level 1 strategy in building a scientific vocabulary (see *SYSTH*, Chapter 10: Building a Scientific Vocabulary). The value in using a Word Cycle comes from taking a broad concept such as an ecosystem, providing a list of terms that could be related to that concept, and then asking students to link these words coherently. Students then learn how terminologies are related, broaden the meaning of terms, and promote collaboration. Teachers are encouraged to use Word Cycle activities with their students in a cooperative manner (e.g., pairings).

Notes

APPENDIX 8: DEVELOPING ASSESSMENT RUBRICS IN SCIENCE

The Nature, Purposes, and Sources of Assessment Rubrics for Science

What Assessment Rubrics Are

Rubrics are assessment tools that identify criteria by which student processes, performances, or products will be assessed. They also describe the qualities of work at various levels of proficiency for each criterion.

The following types of assessment rubrics may be used in classroom assessment:

- **General rubrics** provide descriptions of proficiency levels that can be applied to a range of student processes, performances, or products. Using the same rubric for similar tasks helps teachers manage marking assignments based on student choice. It also helps students internalize the common qualities of effective processes, performances, and products.
- **Task-specific rubrics** describe the criteria used in assessing specific forms, such as using a balance, writing a laboratory report, or calibrating CBL probes. Complex student projects may require a different rubric for each phase (for example, a group inquiry project may require a rubric for collaborative work, information-gathering processes, oral presentations, and written reports).
- **Holistic rubrics** are used to assign a single mark to a process, performance, or product on the basis of its adequacy in meeting identified criteria.
- **Analytic rubrics** are used to assign individual scores to different aspects of a process, performance, or product, based on their specific strengths and weaknesses according to identified criteria. See the Rubric for Assessment of Decision-Making Process Activity in Appendix 9.
- **Checklists** are lists of criteria that do not distinguish levels of performance. They are used to assess the presence or absence of certain behaviours, and are most suitable for assessing processes (for example, "Did the student perform all the necessary steps?"). Because they require "Yes/No" judgements from the assessor, checklists are easy for students to use in peer assessment.
- **Rating scales** ask assessors to rate various elements of a process, performance, or product on a numerical scale. They do not provide complete descriptions of performance at various levels.

Developing Assessment Rubrics: Adapted from Manitoba Education and Training, *Senior 3 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1999) Appendices-3 to -10.

Why Teachers Use Assessment Rubrics

The best assessment tasks ask students to perform the sorts of scientific literacy tasks they will be called upon to perform in real-world situations. They allow students to demonstrate not only the declarative knowledge they have gained, but also the interplay of attitudes, skills, and strategies that constitute their learning. Authentic assessment tasks invite a range of responses and allow students to express their individuality. For all these reasons, assessing scientific literacy is a complex matter.

Assessment rubrics

- help teachers clarify the qualities they are looking for in student work
- ensure that all students are assessed by the same criteria
- help teachers communicate the goals of each assignment in specific terms
- allow teachers within schools, school divisions, and the province to collaborate in assessment
- play an important part in instruction

How Assessment Rubrics Enhance Instruction

The best assessment tools do not simply sort and score student work; instead, they describe it in specific terms. This assessment information

- helps teachers adjust instruction to meet student learning requirements
- tells students what teachers expect and will look for in their work, and helps them to focus their efforts
- allows students to assess their own work using the criteria teachers will use to set goals and to monitor their progress
- aids in the development of metacognition by giving students a vocabulary for talking about particular aspects of their work

Sources of Assessment Rubrics

Teachers develop assessment rubrics in collaboration with students, on their own, and/or with other teachers, or obtain them through published sources.

- **Classroom Development:** Developing assessment rubrics in collaboration with students can be a time-consuming process, but one that has many benefits in instruction and learning. (Both the benefits and the process are explored on the following pages.) Although it may not be possible to involve students in the process in every instance, their experience in developing rubrics will help students to use ready-made rubrics with more understanding.
- **Teacher-Developed:** Teachers develop general performance and product rubrics individually in collaboration within a school or school division. Rubrics must be adapted regularly to reflect student performance levels accurately.

  It is important that teacher-developed rubrics use language that students understand, and that teachers provide an example of work at each level of proficiency. These examples (called anchors or exemplars) illustrate for students the descriptive phrases used in the rubrics.

- **Published Sources:** High-quality assessment rubrics are available in various educational resources. The disadvantage of ready-made rubrics is that they may not be congruent with the learning outcomes targeted in a particular assignment, and may not accurately describe Senior 3 performance levels and criteria.

Developing Rubrics in Collaboration with Students

Student Benefits

Developing rubrics in collaboration with students requires them to look at work samples, and to identify the attributes that make some samples successful and others unsuccessful. Teachers assist students by providing them with the vocabulary to articulate the various elements they see, and by ensuring the criteria are comprehensive and consistent with learning outcomes. This collaborative process in developing rubrics

- requires students to make judgements about the work they see, and to identify the qualities of effective writing, speaking, and representing of science concepts
- results in an assessment tool that students understand and feel they own—they see that assessment criteria are not arbitrary or imposed, but rather express their own observations about what constitutes quality work

The Development Process

For their first experience in designing a rubric, ask students to articulate the criteria they use in making judgements about something in everyday life—the quality of a restaurant, for example. The model rubric that they develop for assessing restaurants may help students grasp how the parts of a rubric work.

Students may also find it helpful to develop rubrics after they have done some preliminary work on the assessment task, and so are familiar with the demands of the particular assignment.

The process of developing assessment rubrics in collaboration with students involves numerous steps.

1. ***Look at student work samples.***

   Develop assessment rubrics by analyzing genuine samples of student work that illustrate the learning outcomes that the assessment task in question addresses. Samples are usually drawn from student work from previous years, used with permission and with names removed. Beginning teachers who do not have files of samples may need to borrow from colleagues.

   Select samples that are clear and characteristic of student work at various levels. Streamline the process by distributing examples at only three levels of proficiency: excellent, adequate, and inadequate. Provide two or three examples of each level. Allow students time to read the examples and to talk about them in groups.

2. ***Describe the work samples.***

   Suggest that students focus on the examples of excellent work first. Pose the question: "What makes this piece successful?" Then ask students to brainstorm attributes of, or criteria for, success. Some of the attributes students list will describe behaviours that are useful in meeting the goals of the work (for example, the topic is stated at the beginning, there are few spelling errors, a graph is used to represent statistical findings).

What rubrics must attempt to articulate, beyond identifying these behaviours, is the essence of a good product or performance. As Wiggins points out, eye contact may be important in the delivery of an oral report, but it is possible to give a dreary talk while maintaining eye contact (V1-5: 6). Together with students, identify the salient qualities of works related to science that are engaging and effective. These may be qualities that are harder to define and illustrate (for example, the speaker has moved beyond a superficial understanding of the subject, the producer of a video is aware of the audience, the writer's voice is discernible in a science journalism piece).

3. ***Develop criteria categories.***

   From the brainstormed list of attributes, select the criteria categories that will make up the assessment rubric. Most rubrics are limited to three to five criteria categories. A greater number makes the rubrics difficult for assessors to use, especially in assessing live performances. Listing too many criteria can also overwhelm or confuse students who use the rubrics for self-assessment and setting goals.

   Develop criteria categories by combining related attributes and selecting three to five that are considered most important. Label the criteria categories in general terms (organization, style, content) and expand them by listing the specific elements to be examined in assessing quality in these criteria (for example, in the "organization" category, the elements may be statement of purpose, topic sentences, transition words and phrases, paragraph breaks, order of ideas).

   Ensure that no essential attribute that defines good performance is left out. This means including elements considered hard to assess (such as style or creativity). Ignoring elements such as these signals that they are not important. Addressing them helps students grasp the things they can do to improve their own work in these areas. If graphical analysis is identified as one criteria category, for example, the rubric may list elements that convey the details of such an analysis (for example, placement of dependent and independent variables, placement of data points, line of "best fit"). It may also provide definitions.

   As students collaborate to develop criteria categories, monitor whether the criteria chosen are related to the intended learning outcomes.

4. ***Decide how many performance levels the rubric will contain.***

   The first rubric students develop will have three performance levels, based on identifying student work samples as excellent, adequate, or inadequate. In later rubrics, students may move to finer distinctions between levels. The number of levels needed to make meaningful judgements regarding the full range of proficiency is best decided by the teacher. If the scale is large (seven levels, for example), finer distinctions can be made, but it may be difficult to differentiate clearly one level from the next. In science, assessment rubrics designed to be used by students as well as teachers generally use three, four, or five performance levels.*

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* Many designers of rubrics advocate a five-level scale. Levels 1, 3, and 5 are developed from an initial sorting of student work into excellent, adequate, and inadequate samples. Levels 2 and 4 describe work that is between these anchor points. Other educators argue that an even-point scale (four or six levels) forces more care in judging than an odd number does; it prevents assessors from overusing a middle category for work that is difficult to assess.

Using the same number of performance levels for various tasks throughout the curriculum has the advantage of giving students and the teacher a common vocabulary in talking about ways to improve performance (for example, "This piece does not have the concrete detail of level 4 writing."). Once the number of criteria categories and performance levels has been determined, a rubric template such as the following can be used in developing rubrics.

		Criteria Categories			
Performance Levels	1				
	2				
	3				
	4				
	5				

5. ***Describe the performance levels.***

In developing the assessment criteria (Step 3), students analyze successful pieces of work. They now fill in descriptions of excellent, adequate, and inadequate performance in all criteria categories.

There are two ways of describing performance levels:

- **Evaluative rubrics** use comparative adjectives (for example, "weak organization").
- **Descriptive rubrics** specify the qualities of work at each performance level with respect to the criteria (for example, "unconnected ideas appear in the same paragraph"). The attributes listed may be negative (for example, "subscripts and coefficients are incorrectly applied"), for sometimes the most telling characteristic of certain levels is their failure to do what they should be doing.

Descriptive rubrics have many advantages over evaluative rubrics. They are more helpful to students because they spell out the behaviours and qualities students encounter in assessing their own and others' work. They also help students identify the things they can address in their own work in order to improve.

When beginning to write descriptive rubrics, students may suggest generally descriptive adjectives (such as "interesting," "boring"), which may not convey information about what an interesting piece looks like, and how they can improve their work in this area. The description needs to state the attributes that make a work interesting, and be written in an acceptable style for scientific communication. Classes may need to begin by using comparative language or general descriptions. As the students and teacher collect examples, they can fine-tune the rubric with specific descriptions.

By the end of this step, students will have a description of performance at three levels. If the class has decided to create a rubric with four, five, or six performance levels, it may be most efficient for the teacher to draft gradations of quality for the middle levels, and present them to the class for revision. These middle levels are the most difficult to write, and call on more experience and expertise in developing a smooth continuum of proficiency.

6. ***Use the assessment rubric for student self-assessment, for teacher assessment, and for instruction.***

   Before using the rubric on an actual assignment, students and the teacher may want to test it against unsorted samples of work from previous years. Applying the rubric to student work helps the class determine whether the rubric accurately describes the qualities of the work they see, and helps students make meaningful distinctions between work at different levels of proficiency. As students become more adept at using the rubric, and when they have internalized the performance levels, the teacher can present them with more diverse samples and assessment challenges.

   Rubrics make it possible for students to assess their own work on the basis of the criteria that the teacher will use. Any differences in scores between a student's and a teacher's assessment can be the subject of profitable and focused discussion in student conferences.

   If numerical scores are required, point values assigned to each level can be totalled. If the teacher and students decide that certain criteria categories should be more heavily weighted than others, the points assigned to these categories can be multiplied by a factor.

   A rubric developed collaboratively can also become a valuable instructional tool, encouraging students to look closely at the specific things they can do to improve a piece of work. If students decide that a writing sample in science is at level 3, for example, they can be asked to work together in groups to improve the work so that it fits the description for level 4.

7. ***Continue to revise the assessment rubric.***

   Any assessment rubric can be considered a work in progress, especially if it is stored on the computer. Both the teacher and students should carefully review the rubric each time they use it, asking, "Do these criteria capture the most important qualities of excellence in this work?" "What other words and phrases can we use to describe work at this level?" In keeping with this, the rubrics appearing in Appendix 9 of this document are intended as templates, open to situational revisions.

APPENDIX 9: ASSESSMENT RUBRICS

Rubric for Assessment of Research Project

Student Name(s) ______________________ Topic/Title ______________________

Criteria	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Source of Information	❒ Only one source of information was used.	❒ Two sources of information were used.	❒ A variety of sources was used.	❒ A wide variety of sources was used in a unique manner.
Information Collected	❒ The information collected was not relevant.	❒ The information collected was relevant to the topic but was not blended into a cohesive piece.	❒ The information collected was relevant to the topic and was somewhat organized into a cohesive piece.	❒ The information collected was relevant to the topic and was carefully organized into a cohesive piece of research.
Organization of Material	❒ The information collected was not organized.	❒ The information was somewhat organized.	❒ The information was organized and contained recognizable sections.	❒ The information was organized and contained recognizable sections that included an introduction, a main body with supporting evidence, and a conclusion that summarized the report.
Presentation of Material	❒ The report was handwritten, contrary to established guidelines.	❒ The report was neatly handwritten. ❒ The report contained a bibliography that was not correctly formatted.	❒ The report was typed. ❒ The report contained graphics. ❒ The report contained a bibliography that was not correctly formatted.	❒ The report was typed and appropriately formatted. ❒ The report contained a title page. ❒ The report contained relevant graphics. ❒ The report contained a complete, correctly formatted bibliography.

Note: *This rubric would vary, depending on the assignment and the presentation format.*

Rubric for Assessment of Decision-Making Process Activity

Student Name(s) ______________________ Topic/Title ______________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Identifies STSE Issue	❒ Cannot identify an STSE issue without assistance.	❒ Shows a basic understanding that an issue could have STSE implications, but does not necessarily differentiate the four areas.	❒ Shows a good understanding of a connection between an issue and its STSE applications. ❒ Shows some awareness of the need for an individual response.	❒ Demonstrates excellent depth and sensitivity in connecting an issue with its STSE implications. ❒ Demonstrates a level of social responsibility.
Evaluates Current Research on Issue	❒ Is able to access a small amount of current research but does not evaluate it.	❒ Demonstrates some ability to recognize the positions taken in the research data but makes no clear evaluative statements.	❒ Secures an array of research, narrow in its scope, but clearly identifies the positions taken. ❒ Can offer personal opinions on issue but not necessarily an evaluation.	❒ Acquires research that is current, relevant, and from a variety of perspectives. ❒ Demonstrates insight into the stated positions and can frame an evaluation.
Formulates Possible Options	❒ Is unable to identify the possible options clearly. ❒ Can formulate options that are not clearly connected to the problem to be solved.	❒ Offers at least one feasible option that is connected to the problem. ❒ Offers other options that may be somewhat related to the problem.	❒ Develops at least two feasible options that are internally consistent and directly address the problem. ❒ Recognizes that some options will fail.	❒ Displays a sophisticated understanding of feasible options that is beyond expectations. ❒ Presents choice of options that demonstrate a reasonable chance of succeeding.
Identifies Projected Impacts	❒ Is unable to foresee the possible consequences of the options selected. ❒ Appears to have a naive awareness of consequences.	❒ Identifies potential impacts of decisions taken in a vague or insubstantial way. ❒ Views most of the feasible options as having projected impacts.	❒ Identifies potential impacts of decisions taken in an organized way. ❒ Views all the feasible options as having projected impacts: some beneficial, some not.	❒ Offers a cost/benefits/risks analysis of each feasible solution. ❒ Constructs an organized report that clearly outlines the impacts of each option.

(continued)

Rubric for Assessment of Decision-Making Process Activity *(continued)*

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Selects an Option and Makes a Decision	❒ Is unable to come to a decision that clearly connects with the problem to be solved. ❒ Requires direction from the outside to make a choice.	❒ Identifies a feasible option, but cannot clearly decide on a plan. ❒ Requires outside influences to stand by a decision to proceed.	❒ Clearly selects an option and decides on a course of action, but others can identify that a better course of action remains untried. ❒ Recognizes potential safety concerns.	❒ Thoroughly analyzes all options collaboratively. ❒ Makes firm decision, justified by the research base, and recognizes most of the safety concerns.
Implements the Decision	❒ Is unable to implement the decision fully, but has an opportunity to modify it. ❒ Lacks the clarity to proceed.	❒ Implements the decision with a recognition that not all details are laid out in advance. ❒ Lacks clarity in having a plan for implementation.	❒ Implements the decision with some clarity of purpose. ❒ Demonstrates confidence that the implementation plan can follow a scientific inquiry approach.	❒ Implements the decision with clarity of purpose, backed by the research base. ❒ Clearly demonstrates that the implementation plan can be carried to completion as inquiry.
Identifies and Evaluates Actual Impacts of Decision	❒ Cannot clearly recognize more than one possible actual impact of the decision. ❒ Cannot effectively evaluate the effects of the decision taken.	❒ Can clearly recognize more than one possible actual impact of the decision taken. ❒ Cannot effectively evaluate the effects of the decision taken in most instances.	❒ Is able to recognize and comment upon the actual observed impacts of the decision. ❒ Demonstrates some ability to evaluate the impacts of the decision.	❒ Is able to recognize and comment deeply upon the actual observed impacts of the decision, noting unforeseen or unique outcomes. ❒ Is able to evaluate the impacts of the decision with ease.
Reflects on the Decision Making and Implementation of a Plan	❒ Begins to demonstrate an awareness of the need to review the implementation plan. ❒ Is reluctant to consider a re-evaluation of the plan.	❒ Reflects upon and intends to communicate the results of the implementation plan. ❒ Has some difficulty in knowing how to proceed with a re-evaluation of the problem-solving plan.	❒ Reflects upon and communicates the results of the implementation plan. ❒ Recognizes how to proceed with a re-evaluation of the problem-solving plan.	❒ Reaches higher order of synthesis in the reflection process. ❒ Has a sophisticated environmental awareness that informs this post-implementation period.

Note: *The above criteria are suggestions only, and will need to be adapted in collaboration with students according to the purpose of the assignment.*

Observation Checklist: Scientific Inquiry—Conducting a Fair Test

Names	Demonstrating Safe Work Habits (workspace, handling equipment, goggles, disposal)	Ensuring Accuracy/ Reliability (repeating measurements/ experiments)	Observing and Recording (carried out during experiment)	Following a Plan	Showing Evidence of Perseverance and/or Confidence	Comments

Note: *A group of students can be selected as a focus for observation on a given day, and/or one or more of the observational areas can be selected as a focus. The emphasis should be on gathering cumulative information over a period of time.*

Lab Report Assessment

Project Title ______________________ Date ____________

Team Members ______________________________________

Area of Interest	Possible Points	Self	Teacher
Formulates Testable Questions: Question is testable and focussed, and the cause-and-effect relationship is identified.			
Formulates a Prediction/Hypothesis: Independent and dependent variables are identified and the prediction/hypothesis clearly identifies a cause-and- effect relationship between these two variables.			
Creates a Plan: All steps are included and clearly described in a logical sequence. All required materials/equipment are identified. Safety considerations are addressed. Major intervening variables are controlled.			
Conducts a Fair Test and Records Observations: Evidence of repeated trials is presented and all data are included. Detailed data are recorded, and appropriate units are used. Data are recorded in a clear/well-structured/ appropriate format for later reference.			
Interprets and Evaluates Results: Patterns/trends/discrepancies are identified. Strengths and weaknesses of approach and potential sources of error are identified. Changes to the original plan are identified and justified.			
Draws a Conclusion: Conclusion explains cause-and-effect relationship between dependent and independent variables. Alternative explanations are identified. Hypothesis is supported or rejected.			
Makes Connections: Potential applications are identified and/or links to area of study are made.			
Total Points			

Peer/Self-Assessment Sheet for Poster Project in Solving an Environmental Problem

Name of Peer Evaluator: ____________________

Name of Author/Presenter: ____________________

Total Mark: __________

Score the poster you are assessing, using the following scales. Circle only one number per category. The higher the number circled, the better that poster project is at showing what environmental problem is being dealt with and how to reduce its negative effects.

Title clearly states what information is shown on the poster	None 0	1	Incomplete 2	3	Complete 4
Content makes clear which environmental problem is being dealt with in the poster and the solution to that problem is practical	Unclear, impractical 0	1	Somewhat clear, somewhat practical 2	3	Very clear, very practical 4
Legends/Labels—symbols/features identified by labels or legend	None 0	1	Some 2	3	All 4
Printing—labels are neatly printed so they are easy to read	No 0	1	Somewhat 2	3	Yes 4
Organization—information is carefully organized so reader understands it easily	No 0	1	Somewhat 2	3	Yes 4
Overall Appearance—general impression of poster related to its neatness, care in drawing, ease of understanding	Poor 0	1	Good 2	3	Excellent 4

Rubric for the Assessment of Student Presentation

Student Name(s) ______________________________ Topic/Title ______________________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Organization	❒ Presentation shows poor organization and lack of preparation.	❒ Presentation shows signs of organization, but some parts do not seem to fit the topic.	❒ Presentation is organized, logical, and interesting.	❒ Presentation is well organized, logical, interesting, and lively.
Preparation	❒ Some student preparation is shown.	❒ A fair amount of student preparation is shown.	❒ An adequate amount of student preparation is shown.	❒ A great deal of student preparation is shown.
Content	❒ Small amount of material presented is related to the topic.	❒ Some material presented is not related to the topic.	❒ Almost all material presented is related to the topic.	❒ All material presented is related to the topic.
Language	❒ Language used is hard to follow and understand.	❒ Some language used is hard to follow and understand.	❒ Most language used is easy to follow and understand.	❒ Language used is well chosen and is easy to follow and understand.
Format	❒ Poor use of aids and support materials (diagrams, overheads, maps, pictures); few support the topic.	❒ Adequate use of aids and support materials; most support the topic.	❒ Good use of aids and support materials; almost all support the topic.	❒ Excellent use of aids and support materials; all aids support the topic.
Delivery	❒ Many words are unclear or spoken too quickly or slowly; voice is monotonous; no pausing for emphasis; voice is too low to be heard easily.	❒ Some words are unclear or spoken too quickly at times; voice is somewhat varied; some pausing for emphasis; voice is sometimes too low to be heard easily.	❒ Most words are clear and generally spoken at the correct speed; voice is often varied, interesting, frequent pausing for emphasis; voice is loud enough to be heard easily.	❒ Words are clear and generally spoken at the correct speed; voice is frequently varied, interesting, effective pausing for emphasis; voice is loud enough to be heard easily.
Audience	❒ Audience is not involved or interested.	❒ Audience is somewhat involved, and sometimes interested.	❒ Audience is involved and interested.	❒ Audience is very involved and interested.

Note: *The above criteria are suggestions only, and will need to be adapted in collaboration with students according to the purpose of the assignment.*

Rubric for Assessment of Class Presentations

Student Name(s) ________________________ Topic/Title ________________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Content	❐ No understanding of the topic was evident.	❐ Basic understanding of the topic was evident. ❐ No attempt made to relate material presented to students' own experiences.	❐ Good understanding of the topic was evident. ❐ Knowledge was thorough and detailed. ❐ Attempt made to relate the material presented to students' own experiences.	❐ Excellent depth of understanding was evident. ❐ Material presented went beyond what was required. Excellent research. ❐ Material presented related to students' own experiences.
Interest and Enthusiasm	❐ Presenter(s) displayed little interest in and enthusiasm for the topic of the presentation. ❐ The class conveyed limited attentiveness during the presentation.	❐ Presenter(s) showed some interest in and enthusiasm for the topic. ❐ The class showed some attentiveness during the presentation.	❐ Presenter(s) clearly showed interest in and enthusiasm for the topic. ❐ The class was noticeably attentive during the presentation.	❐ Presenter(s) showed exceptional interest in and enthusiasm for the topic. ❐ The class was keenly attentive during the presentation.
Clarity and Organization of Material	❐ The information presented was confusing.	❐ The information presented was somewhat vague. ❐ The presentation reflected some organization.	❐ The information was clearly presented. ❐ The presentation was well organized.	❐ All information was relevant and clearly presented. ❐ The presentation was exceptionally well organized. ❐ Main points were emphasized and reinforced with appropriate examples.
Use of Visual Aids	❐ Visual aids were not used.	❐ A few visual aids were used. ❐ Visual aids were not well done. ❐ Visual aids used were somewhat relevant to the presentation.	❐ Visual aids were used. ❐ Visual aids were quite well done. ❐ Visual aids were relevant to the presentation.	❐ Strong visual aids were used with care. ❐ Visual aids were clear and extremely well done, showing effective use of colour. ❐ Visual aids were designed to emphasize and strengthen the presentation and were successful.

Note: *This rubric would vary according to the assignment and the presentation format.*

Rubric for Assessment of Research Skills

Student Name(s) ____________________ Topic/Title ____________________

Research Skills	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Ability to formulate questions to identify problems for research purposes	❒ Shows limited ability	❒ Shows some ability	❒ Shows general ability	❒ Shows consistent and thorough ability
Ability to locate relevant primary and secondary sources of information	❒ Unable to locate	❒ Somewhat able to locate	❒ Generally able to locate	❒ Always or almost always able to locate
Ability to locate and record relevant information from a variety of sources	❒ Unable to locate and record	❒ Somewhat able to locate	❒ Generally able to locate and record	❒ Always or almost always able to locate and record
Ability to organize information related to identified problem(s)	❒ Shows limited ability	❒ Shows some ability	❒ Shows general ability	❒ Shows consistent and thorough ability
Ability to analyze and synthesize information related to identified problems	❒ Shows limited ability	❒ Shows some ability	❒ Shows general ability	❒ Shows consistent and thorough ability
Ability to communicate results of inquiries using a variety of appropriate presentation forms (oral, media, written, graphic, pictorial, other)	❒ Unable to communicate	❒ Somewhat able to communicate	❒ Generally able to communicate	❒ Always or almost always able to communicate

Note: *This rubric would vary according to the assignment and the presentation format.*

Rubric for Assessment of Scientific Inquiry

Student Name(s) ______________________ Topic/Title ______________________

Criteria	Performance Levels			
	Beginning **1**	**Developing** **2**	**Accomplished** **3**	**Exemplary** **4**
Position Statement/ Proto-Abstract (Not intended to be an abstract in the style and purpose of scientific journals)	The student ❒ does not discuss the relevance of the inquiry	The student ❒ offers some discussion but no clear explanation of the importance or goals of the inquiry	The student ❒ discusses the importance of the inquiry but not its relationship to the curriculum or to the real world	The student ❒ clearly summarizes the inquiry, highlights relevant information, and makes critical connections
Objective/Purpose/ Testable Question (Formulation of scientific questions and hypotheses)	❒ omits an objective/ purpose, or states an objective not relevant to the problem under investigation	❒ states an objective that is not a hypothesis or a testable question, but identifies variables to be investigated	❒ states a testable question related to the problem, and identifies variables to be investigated	❒ clearly states a testable hypothesis that addresses the problem, and clearly delineates the variables to be tested
Procedure (Design of the investigation)	❒ does not outline reproducible steps in the procedure ❒ shows some use of methodology, but no account of experimental or systematic error	❒ outlines clear, ordered steps in the procedure ❒ identifies need for treatment of variables, but does not state how this will be achieved	❒ outlines clear, ordered steps in the procedure ❒ identifies need for treatment of *specific* variables, and states how this will be achieved	❒ outlines clear, ordered steps in the procedure ❒ identifies need for treatment of *specific* variables, and states how this will be achieved ❒ provides a concise summary of the procedure
Data Collection	❒ collects some data that can be traced to the investigation itself, but data are inaccurate and incomplete	❒ provides reasonably complete data, organized in tabular form (+/- titles) ❒ gives no indication of use of basic accuracy and precision techniques (e.g., significant figures)	❒ provides complete data, organized in tabular form (+/- titles) ❒ demonstrates some use of basic accuracy and precision techniques (e.g., significant figures)	❒ provides complete data with error analysis, organized in tabular form (+/- titles) ❒ demonstrates use of basic accuracy and precision techniques (e.g., significant figures)

(continued)

Rubric for Assessment of Scientific Inquiry *(continued)*

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Beginning 1	**Developing** 2	**Accomplished** 3	**Exemplary** 4
Analysis and Interpretation	❒ provides improper, incomplete graphical representation of data ❒ attempts no "fit" for plotted data ❒ requires abundance of supervision	❒ provides proper graphical representation of data ❒ attempts to fit a *linear* regression line to data ❒ ensures axes are labelled correctly and positioned consistently with identified variables	❒ provides proper graphical representation of data ❒ shows some evidence of mastery in fitting a *linear* regression line to data, and states *slope* and y-intercept ❒ ensures axes are labelled correctly and positioned consistently with identified variables	❒ provides proper graphical representation of data in a variety of forms ❒ shows evidence of mastery in fitting a *non-linear* regression line to data, and states *slope* and y-intercept ❒ ensures axes are labelled correctly and positioned consistently with identified variables ❒ demonstrates understanding of how variables relate to a model equation
Application/ Discussion of Scientific Results and Concepts	❒ attempts to explain inquiry results in terms of random error alone ("where I went wrong") ❒ makes inaccurate, improper, or no conclusions based on data	❒ attempts to connect inquiry results with model systems encountered in class experience ❒ identifies where systematic error may have caused problems	❒ draws accurate and detailed comparison between the system under investigation and what could occur in an ideal system ❒ makes use of introductory statistical analyses ❒ identifies "outliers" in data set(s)	❒ draws accurate and detailed comparison between the system under investigation and what could occur in an ideal system ❒ uses a range of statistical analyses ❒ identifies "outliers" in data set(s)
Independence Factors (Reliance on assistance)	❒ requires extensive assistance from text sources and classmates to do inquiry tasks ❒ requires constant teacher supervision	❒ requires little assistance to complete inquiry tasks ❒ is able to internalize teacher intervention, and work independently afterward	❒ requires no assistance to complete inquiry tasks ❒ demonstrates cooperation with partners ❒ resists efforts of others to assist	❒ requires no assistance to complete inquiry tasks ❒ demonstrates cooperation with partners ❒ seeks opportunities to discuss procedures and results with others

Notes

Forensic Sciences:
A Crime Scene Investigation Unit

for Senior 3 Current Topics in the Sciences

CONTENTS

INTRODUCTION

> I never guess. It is a shocking habit—destructive to the logical faculty. What seems strange to you is only so because you do not follow my train of thought or observe the small facts upon which large inferences may depend.
>
> Sherlock Holmes, *The Sign of Four*

Forensic Sciences: A Crime Scene Investigation Unit for Senior 3 Current Topics in the Sciences contains suggested essential understandings and possible activities, assignments, investigations, and assessment ideas for curriculum implementation. What is included here is by no means exhaustive or restrictive; nor is it expected that all suggested activities will be used. The essential understandings are not arranged in order of importance or priority, and may be addressed in any order that produces a coherent sequence. Teachers decide which essential understandings will allow them to address the specific learning outcomes that frame Senior 3 Current Topics in the Sciences.

Teachers are encouraged to choose from this selection of suggested content, activities, investigations, and assignments, of varying levels of difficulty, and to develop the unit further by using some of their own content and activities. Many online and print resources are available to supplement the treatment of Forensic Sciences in the classroom. (See the Resources cited at the end of this unit.)

Rationale

Solving mysteries is a challenge many people enjoy. If they take a scientific approach, they are likely to use forensic sciences to examine evidence and to solve crimes. Students are commonly exposed to crime situations in the media, both fictional and real, and are likely aware that forensic sciences are used to solve crimes, as many current television programs and popular authors use the science of forensics to develop their dramas. However, students may not be aware of the methodology used by law enforcement personnel. By becoming involved in a simulated crime scene, students will see how forensic investigators apply scientific skills and processes in a problem-solving capacity.

A *forensics team* is a group of scientists who work together performing different jobs to solve crimes or to identify people. A forensics team may observe the crime scene and gather evidence such as hair and fibre samples, fingerprints, and tissue samples. An *investigative team* includes forensic scientists with varying areas of expertise, including toxicology, forensic biology, forensic entomology, chemistry, forensic psychology, forensic odontology, forensic anthropology, bloodstain pattern analysis, and weapons specialists. The job of forensic investigators is to use science and technology to perform tests on the evidence collected. The results from these tests can then be used to support a theory of guilt or innocence.

Forensic scientists use the same instruments and techniques used by scientists doing other types of research, including microscopes, computers, gas chromatographs, and lasers. As science has advanced, so has the ability to gather evidence and to solve crimes. At crime scenes, portable lasers provide special lighting. Imaging technology lets a police officer instantly send a photograph or fingerprint image to a central data bank for identification. Computers can enhance pictures taken by a security camera at a crime scene. New chemicals allow the visualization of otherwise unseen fingerprints. Lasers can vaporize tiny portions of a paint specimen to determine the exact paint used on a car in a hit-and-run case. A single cell can provide deoxyribonucleic acid (DNA) that molecular biology techniques can match with a suspect.

The Forensic Sciences unit was developed to allow students to integrate a number of scientific disciplines and to practise a variety of scientific skills and processes, including making comparisons, classifications, observations, measurements, and predictions, as well as formulating hypotheses, manipulating variables, and interpreting data. The unit consists of individual activities, each of which includes teacher and student pages. The unit can be designed to include any activities teachers (or students) may wish to incorporate into their forensics learning experience.

The student learning activities are highly variable, and can be structured and sequenced according to student interest, available materials, and local resources. Solving a crime requires the use of critical thinking skills that will integrate several science disciplines and be useful across the curriculum.

Integrating the Sciences

As students explore the topic of forensic sciences, many sciences may naturally be integrated. The following table outlines suggested essential understandings and their possible connections to the major science disciplines. It is important to recognize, and reinforce with students, that it is common for diverse specialties to operate simultaneously in scientific investigation.

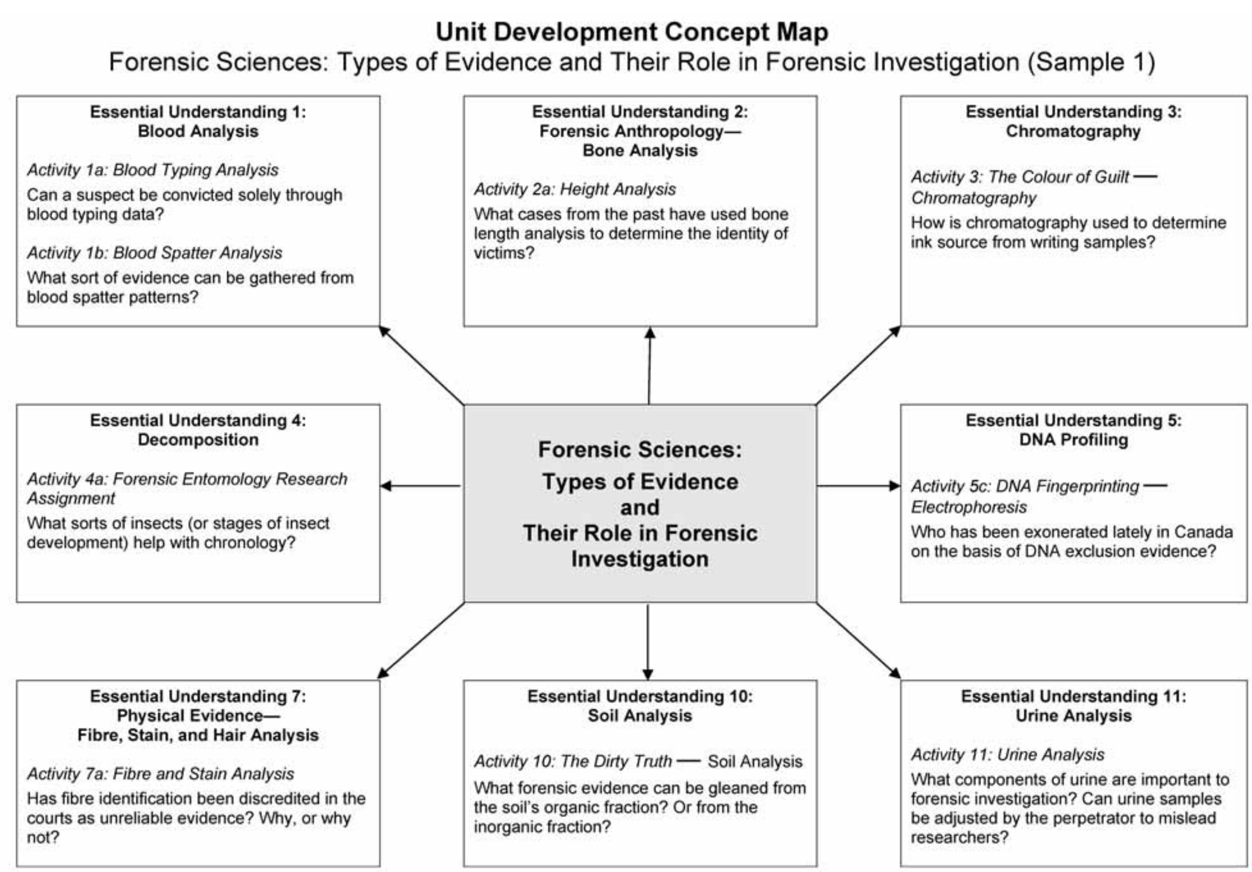
Essential Understandings					
Number	**Essential Understanding**	**Biology**	**Chemistry**	**Physics**	**Geo-Sciences**
1	**Blood Analysis**	• Blood typing	• Chemical reactions	• Blood spatter analysis	
2	**Forensic Anthropology—Bone Analysis**	• DNA • Bones			
3	**Chromatography**		• Solubility		
4	**Decomposition**	• Entomology • Life cycles			• Soil
5	**DNA Profiling**	• DNA	• Chemical extraction		
6	**Fingerprinting**				
7	**Physical Evidence—Fibre, Stain, and Hair Analysis**	• Physical characteristics			
8	**Handwriting Analysis**				
9	**Chemical Detection**		• Properties • Chemical reactions		
10	**Soil Analysis**				• Soil characteristics
11	**Urine Analysis**	• Kidney function • Disease	• Chemical reactions		
12	**Further Analyses**				

Planning the Forensic Sciences Unit

A unit plan evolves from a particular topic. A number of essential understandings within the area of interest could be generated either by the teacher alone or with the help of students. *Essential understandings* are concepts, skills, or bodies of knowledge that are crucial for students to comprehend to develop an in-depth understanding of the topic. The essential understandings will likely determine the specific learning outcomes (SLOs) for general learning outcome (GLO) D (Essential Concepts).

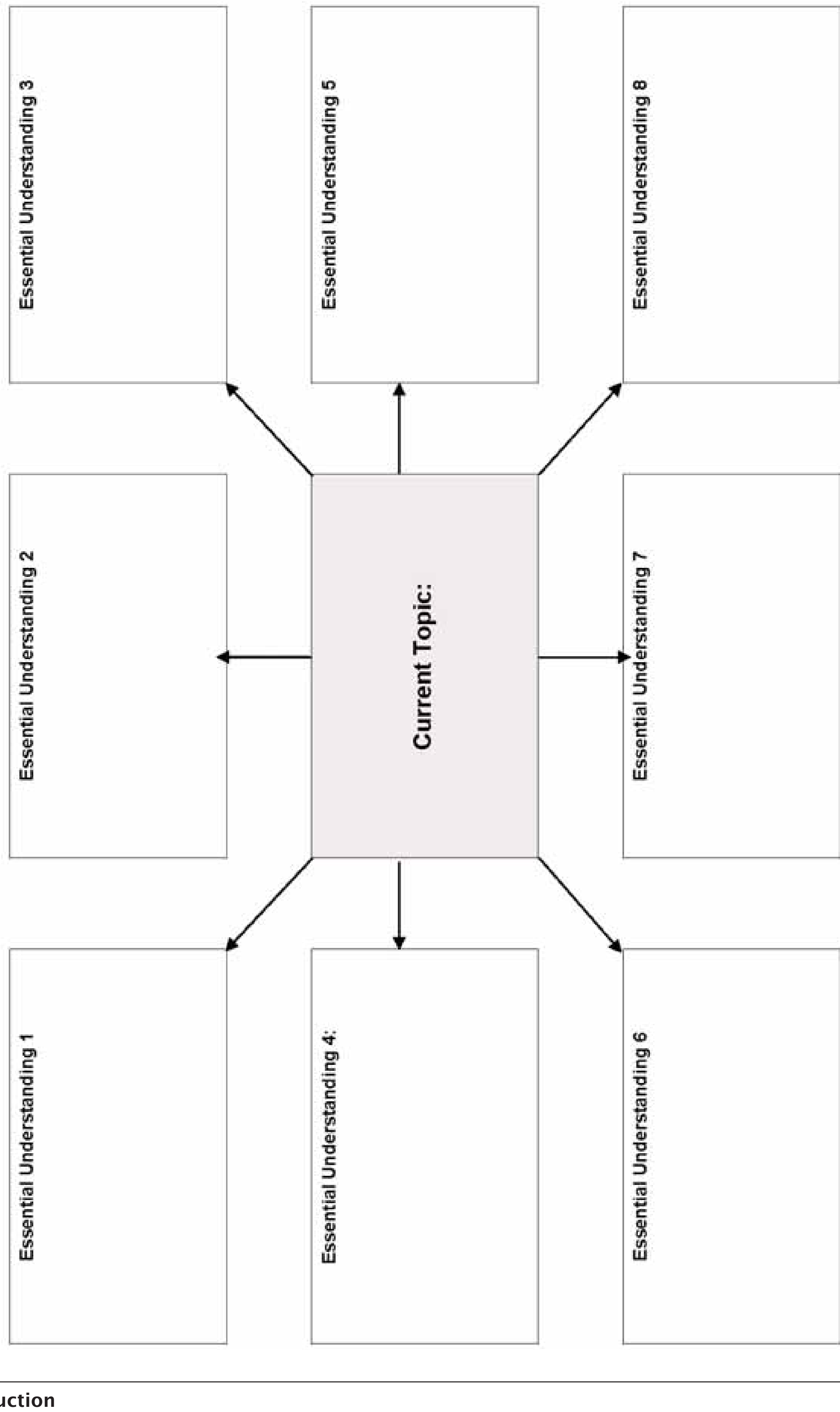
The number of essential understandings generated will depend upon the topic, the amount of time allotted to the unit, and the interest of students. There may be essential understandings of particular interest to students that develop during the presentation of the unit, and teachers are encouraged to pursue these. While the size of a unit may vary (for example, 10 to more than 50 hours), teachers are encouraged to pursue a depth of treatment that is manageable and connected to the SLOs identified for the Senior 3 Current Topics in the Sciences curriculum. (Teachers implemented the Draft version of the Forensic Sciences unit with timelines spanning 25 to 65 hours.)

In developing the Forensic Sciences unit, teachers may choose to use planning tools such as the Unit Development Concept Map (with possible essential questions) or the Unit Development Using Essential Understandings Approach shown in the samples and templates that follow. Teachers involved in field validation work found these planning tools useful.



Note: There may be more or fewer than eight essential understandings. The arrows serve to connect essential understandings to the topic.

Unit Development Concept Map



Note: There may be more or fewer than eight understandings. The arrows serve to connect essential understandings to the topic.

Unit Development
Using Essential Understandings Approach
Forensic Sciences: A Crime Scene Investigation Unit (Sample 1)

Current Topic: Forensic Sciences: Crime Scene Investigation

Essential Understanding: 1. Blood Analysis

			SLO Tracking
Knowledge:		• There is a relationship between the distance a drop of blood falls and the diameter of its spatter. • There is a relationship between the angle and direction a drop of blood falls and its spatter pattern.	SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.
Skills:		• Measurement • Collaboration • Data Analysis	SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
Activities:		• Blood Spatter Analysis Lab	SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
Assessment:	Formative	• Blood Spatter Analysis Lab	SLO C1 SLO C4 SLO C5
	Summative	• Blood Spatter Analysis Lab Report	SLO A2 SLO C4 SLO D3

<table>
<tr><th colspan="4">Unit Development
Using Essential Understandings Approach</th></tr>
<tr><td colspan="2">Current Topic:</td><td colspan="2"></td></tr>
<tr><td colspan="2">Essential Understanding:</td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td>SLO Tracking</td></tr>
<tr><td colspan="2">Knowledge:</td><td>•</td><td></td></tr>
<tr><td colspan="2">Skills:</td><td>•</td><td></td></tr>
<tr><td colspan="2">Activities:</td><td>•</td><td></td></tr>
<tr><td rowspan="2">Assessment:</td><td>Formative</td><td>•</td><td></td></tr>
<tr><td>Summative</td><td>•</td><td></td></tr>
</table>

Linking to Specific Learning Outcomes

After developing the initial unit plan, teachers may use an SLO Tracking Chart to link instructional strategies and student learning activities to the **specific learning outcomes (SLOs)**.

A single unit will not necessarily address all SLOs. The SLOs are cumulative in nature, and it is expected that a student will have the opportunity to achieve all outcomes by the end of Senior 3 Current Topics in the Sciences.

An SLO Tracking Chart will assist teachers in determining whether each SLO has been addressed at least once during curriculum implementation. Many SLOs will be addressed more than once by virtue of the design of interdisciplinary units.

The following SLO Tracking Chart is an example of a specific learning outcome audit for a set of student learning activities in a Forensic Sciences unit. A template of the SLO Tracking Chart follows the sample.

SLO Tracking Chart

Forensic Sciences: A Crime Scene Investigation Unit (Sample 1)

Learning Outcomes	Forensic Sciences Activities								
	Blood Typing Analysis	Blood Spatter Analysis	Height Analysis	The Colour of Guilt—Chromatography	Forensic Entomology Research Assignment	DNA Fingerprinting—Electrophoresis	Fibre and Stain Analysis	The Dirty Truth—Soil Analysis	Urine Analysis
	1a.	1b.	2a.	3.	4a.	5c.	7a.	10.	11.
NATURE OF SCIENCE AND TECHNOLOGY **GLO A: Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.**									
SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.	•					•			
SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.		•					•		
SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.									
SLO A4: Recognize that science and technology interact and evolve, often advancing one another.	•					•			
SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.				•		•		•	
SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT **GLO B: Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.**									
SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.						•			
SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.							•		
SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.	•								•
SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.				•	•				
SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.								•	

(continued)

SLO Tracking Chart

Forensic Sciences: A Crime Scene Investigation Unit (Sample 1) (Continued)

Learning Outcomes	Forensic Sciences Activities								
	Blood Typing Analysis	Blood Spatter Analysis	Height Analysis	The Colour of Guilt—Chromatography	Forensic Entomology Research Assignment	DNA Fingerprinting—Electrophoresis	Fibre and Stain Analysis	The Dirty Truth—Soil Analysis	Urine Analysis
	1a.	1b.	2a.	3.	4a.	5c.	7a.	10.	11.
SCIENTIFIC AND TECHNOLOGICAL SKILLS AND ATTITUDES **GLO C: Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.**									
SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.	•		•				•		
SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.									
SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.						•			
SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.					•				•
SLO C5: Work cooperatively with others and value their ideas and contributions.		•	•			•			
ESSENTIAL CONCEPTS **GLO D: Explore, understand, and use scientific knowledge in a variety of contexts.**									
SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.	•		•			•	•	•	
SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.					•				•
SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.		•		•		•			
SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.					•				

Note: This chart is intended to highlight how student learning activities connect to the learning outcomes. It is not a comprehensive treatment of all activities in the sample Forensics Sciences unit.

SLO Tracking Chart

Learning Outcomes	Activities								
	1.	2.	3.	4.	5.	6.	7.	8.	
NATURE OF SCIENCE AND TECHNOLOGY **GLO A: Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.**									
SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.									
SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.									
SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.									
SLO A4: Recognize that science and technology interact and evolve, often advancing one another.									
SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.									
SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT **GLO B: Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.**									
SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.									
SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.									
SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.									
SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.									
SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.									

(continued)

SLO Tracking Chart *(continued)*									
Learning Outcomes	**Activities**								
	1.	2.	3.	4.	5.	6.	7.	8.	
SCIENTIFIC AND TECHNOLOGICAL SKILLS AND ATTITUDES **GLO C: Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.**									
SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.									
SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.									
SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.									
SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.									
SLO C5: Work cooperatively with others and value their ideas and contributions.									
ESSENTIAL CONCEPTS **GLO D: Explore, understand, and use scientific knowledge in a variety of contexts.**									
SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.									
SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.									
SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.									
SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.									

Note: This chart is intended to highlight how student learning activities connect to the identified learning outcomes.

Establishing a Crime Scene

The Location

Choose an area with limited access to students, such as a storage area or an extra room at school, so that the crime scene can remain set up for continued observations. You may also choose to have the crime scene take place at another location (such as close to a pond), leaving evidence (such as soil, vegetation, and/or insects) indicating the area associated with the body found at the crime scene.

Storyline

Determine the victim(s) and suspect(s) and their relationship(s) to each other (if one can be established). Establish a scenario where all suspects have the motive, opportunity, and means to be involved in the crime, but the outcome is undetermined in advance. It is hoped that students will manage the evidence.

Suspects

Once you have established a group (about five) of suspects, decide whether to introduce them in written form or to have individuals (teachers) act out the roles. Each suspect should have the motive, opportunity, and means to be involved in the crime. Trace evidence may link a number of different suspects to the crime scene.

- **Motive:** A motive is a reason for committing the crime. Possible motives are passion, jealousy, greed, and revenge. Motive is usually determined through interviews and research.
- **Opportunity:** A suspect who can be placed at the scene of the crime, or was able to get to the scene of the crime within a certain time frame, can be said to have had opportunity.
- **Means:** A suspect considered by investigators to have been able to commit the crime can be said to have had means.

As an extension, you may want to add a witness or suspect who has been seen fleeing the crime scene.

Alibis

Establish alibis for some or all of the suspects (some alibis may be false). This information may be presented to students in written form, as in a police interview with the suspect. As the investigation proceeds, the suspect(s) might be subjected to several interviews where they might add new information and/or change their stories. You might choose to distribute information from the interviews at specific intervals. You might also provide your suspects with a written script and allow the forensic investigative teams to interview the suspects.

Suspect Files

You may wish to establish “suspect files” within the class, to which information can be added during the course of the investigation.

Evidence

Evidence is any statement or material object from which reasonable conclusions can be drawn. It is a broad category embracing anything perceptible to the five senses, including documents, exhibits, facts agreed to by both sides, and the testimony of witnesses. Evidence in a criminal trial concerns the intent, motive, means, and opportunity to commit a crime.

In general, evidence is divided into two categories: circumstantial and physical.

- **Circumstantial evidence** consists of information gleaned from witnesses and documents that point to an individual as the perpetrator of a crime.
- **Physical evidence** consists of actual objects, bodies, weapons, body-fluid stains, fingerprints, hairs, fibres, and so on, that are associated with the crime and may be linked to the perpetrator.

It is the work of forensic scientists to examine the physical evidence and, using the methods of science, to reconstruct the events that constituted the crime. The prosecutor must then combine this data with statements of witnesses and evidence from documents, such as correspondence, telephone records, and credit card receipts, to develop an overall theory of the case, which can be presented in court.

Crime Scene Details

Establish crime scene details such as the following:

- If possible, mark off the crime scene using police or yellow tape (Crime Scene—Do Not Cross).
- For the body, use a skeleton, a large doll, clothes stuffed with paper and a mask head, or simply an outline of the body marked with tape or chalk on the floor.
- Plant “trace” evidence at the crime scene (see Planting Evidence at the Crime Scene on the following page). Leave it all at once or control the gathering of evidence by leaving a few items at a time and having students return to the crime scene to gather more. Creating a tabular format sheet to track evidence will be useful in providing linkages to possible suspects.
- Consider leaving some red herrings as well, such as cigarette butts, empty cans, earrings, or candy wrappers.

Use a table such as the following to map out the types of evidence you plant at the crime scene and the suspect to whom it links.

Planting Evidence at the Crime Scene															
Evidence	Blood Typing	Blood Spatter	Bone/Foot Length	Chromatography	Decomposition	Dental	DNA	Fibres	Fingerprints	Hair	Handwriting	Powder	Soil	Urine	
Victim															
Suspect A															
Suspect B															
Suspect C															
Suspect D															
Suspect E															

Collecting and Storing Evidence

Great care must be taken in collecting, labelling, and preserving any evidence connected with a crime. The police must be able to prove that the evidence has always been in their possession from the time it was taken at the crime scene until the time it appears in court. Anyone who has access to the material must be documented. Police must prove that the object shown in court is the same object that was tested in the laboratory. If this cannot be proven, the judge may rule that the chain of custody has been broken and the object may not be admitted into evidence. As soon as an object is found, it is placed in a container, sealed, and labelled. The place where the object was found and when it was found are noted by the officer who also initials the label. When the evidence goes to the police station or forensic lab, it is placed in a locked evidence room to which only a few people have access. An exact record is maintained of everyone who has had the evidence in his or her possession.

For the Forensic Sciences unit, you may wish to make the following preparations:

- Provide students with gloves for collecting evidence.
- Use zippered plastic bags to store evidence gathered at the crime scene and from the suspects. Label bags with a code (such as Exhibit # 17-34067) for which you maintain the key, or with the suspect's name and address.
- Prepare a box labelled Evidence Locker. Investigative teams must sign out the evidence stored in this box before examining it (providing exhibit number, date, and signature).

Forensic Investigation Lab Book

The information collected by the forensic investigative teams may be written up in a forensic database or in a *Forensic Investigation Lab Book*. You may wish to have individual team members initial their work to ensure that each member is contributing to the investigation. You may choose to allow them access to this information at any time, even during a quiz or final examination. Students are encouraged to keep their database or lab books neat and to organize the information in a manner that allows them to retrieve information quickly.

Instructional Overview

An overview of the steps and processes involved in the Forensic Sciences unit follows:

1. **Establish Forensic Investigative Teams**
   Teams research the various types of forensic investigation specialties, and individual team members choose to be specialists in particular fields.

2. **Introduce the Crime**
   Describe the crime to students and provide the teams with some initial investigative reports.

3. **Organize the *Forensic Investigation Lab Book***
   Students begin to organize the format of their lab books.

4. **Create Evidence Boards**
   Students may also display their evidence in flow charts on evidence boards. These may remain set up on the classroom wall.

5. **Consider Using Introductory Activities**
   You may choose to have students engage in introductory observational and logical thinking activities such as the following:
   - Students solve mathematical problems involving logic.
   - Students form two lines of pairs facing each other for 30 seconds. Students in one line then turn away, and the students in the other line change one thing about their appearance (for example, untie shoe, remove earring, flip hair). The students in the first line then turn back and determine what is different.
   - Someone runs quickly (and without warning) through the room. Students describe the individual.
6. **Document the Crime Scene**
   Investigative teams observe the crime scene. They make diagrams with reference points, photographs, or videos.
7. **Gather Evidence**
   Students gather and bag evidence, either all at once or at intervals during the progression of the unit. You may also choose to provide students with written information, such as witness interviews, police reports, and newspaper reports.
8. **Research**
   Students research various aspects of the case, including the history of the development of specific analyses.
9. **Analyze the Evidence**
   Students examine the evidence from the crime scene and compare it to samples from suspects.
10. **Prepare Investigation Report**
    Students write a summary report of their investigation, which includes a description of what they think happened, with evidence to support this scenario. Explain how physical evidence collected at the scene of a crime could be used to assist in an arrest and conviction of a suspect.
11. **Tie Together All the Evidence/Reporting**
    Provide various opportunities for students to examine evidence and data gathered in the crime scene investigation and to make conclusions based on the findings.
    a. **Hold a Mock Trial**
       Students may engage in a mock trial, assuming the various roles:
       - judge
       - jury
       - accused
       - defence team
       - prosecution team
       - witnesses
       - expert witnesses

The evidence should be examined thoroughly, and all data questioned and analyzed. Conclusions must be related to actual evidence. The division of duties could include the opening argument, closing statement, presentation of each type of technical evidence, direct examination, and cross-examination. Students assigned to the jury will hear the case and then deliberate before the class. This will allow all students to have a speaking role.

b. **Write and Present a Fictional Crime Scene Drama**
Groups of students (preferably re-mixed from their investigative teams) write and present a crime scene drama. The evidence should be examined thoroughly, and all data questioned and analyzed. Conclusions must be related to actual evidence.

c. **Write and Present a Fictional Crime Scene Short Story**
Students (groups or individuals) write a fictional crime scene story. The evidence should be examined thoroughly, and all data questioned and analyzed. Conclusions must be related to actual evidence.

d. **Prepare News Reports**
Students (groups or individuals) write a series of news reports (fact or fiction) based on a crime scene investigation. The evidence should be examined thoroughly, and all data questioned and analyzed. Conclusions must be related to actual evidence.

Assessment

Assessment strategies may include the following:

- lab reports
- daily log of investigative team's activities
- *Forensic Investigation Lab Book*
    - — research notes
    - — crime scene notes
    - — diagrams
    - — lab investigations
    - — summaries
    - — conclusions
- evidence summary and conclusions
- presentation
- final report

Crime Scene Kit

Criminal investigators use a variety of materials and instruments in collecting evidence from a crime scene. These materials may include the following:

- crime scene tape
- chalk
- hand-held magnifying glass
- flashlight
- tweezers
- swabs
- tape lifts
- trace evidence vacuum
- sketchpad, logbook, pen
- camera
- video recorder
- evidence bags
- seals
- paper bags
- envelopes
- disposable clothing
- gloves
- masks
- string
- measuring tools
- coloured evidence flags
- adhesive lint pick-up roller
- portable alternative light source (infrared, ultraviolet, laser)
- fingerprinting kit (powder, brushes, lifting tape, cards, stamp/ink pad)
- casting kit (casting powder, mixing bowl, fixative)—for tire prints or footprints
- laser trajectory kit
- gunshot residue kit
- blood-detection reagents (phenolphthalein, leucomalachite, luminol)
- serology kit
- insect specimen jars
- "hazmat" (hazardous materials) kit—to assess composition of toxic materials

Crime Lab Equipment

Crime labs may include equipment such as the following:

- beakers
- flasks
- burets
- pipets
- graduated cylinders
- test tubes
- watch glasses
- stereoscopic microscopes
- compound microscopes
- phase contrast microscopes
- spectroscope
- spectrograph
- spectrometer
- spectrophotometer
- electron microscope
- ultraviolet lighting
- gas chromatograph
- mass spectrometer
- electrophoresis chamber
- nuclear reactor
- refractometer
- liquid chromatography apparatus

ESSENTIAL UNDERSTANDING 1: BLOOD ANALYSIS

Teacher Background

Blood consists of a solid portion (red blood cells, white blood cells, platelets) suspended in a watery plasma. Many chemicals are also suspended or dissolved in the plasma, including proteins, sugars, fats, salts, enzymes, and gases.

One way in which blood may be characterized is by the presence or absence of molecules located on the surfaces of the red blood cells. In the ABO blood typing group, there are two types of chemical molecules or antigens found on the red blood cells: A and B.

- If a red blood cell has only A antigens on it, it is type A.
- If the red blood cell has only B antigens on it, it is type B.
- If the red blood cell has both A and B antigens on it, it is type AB.
- If neither A nor B antigens are on the surface, it is type O.

If two different blood types are mixed together, the blood cells may clump together in the blood vessels, with potentially fatal results. Blood types must be matched before blood transfusions take place.

- Type A blood groups produce antibodies against B antigens and, hence, can accept only type A or type O blood in a blood transfusion.
- Type B blood groups produce antibodies against A antigens and, hence, can accept only type B or type O blood in a blood transfusion.
- Type AB blood groups produce neither anti-A nor anti-B antibodies and, hence, can accept type AB, type A, type B, or type O blood in a blood transfusion.
- Type O blood groups produce both anti-A and Anti-B antibodies and, hence, can accept only type O blood in a blood transfusion.

Because of these patterns, a person with type O blood is said to be a universal donor. A person with type AB blood is said to be a universal receiver. In general, however, it is still best to mix blood of matching types and Rh factors. Rh (rhesus) factor refers to the presence (Rh+) or absence (Rh-) of the D antigen on the surface of the blood cell.

Response of Blood Types to Antisera

Blood Type	Antigen (Surface Molecule)	Antibody Produced	Agglutination with Anti-A Serum	Agglutination with Anti-B Serum
A	A	Anti-B	Yes	No
B	B	Anti-A	No	Yes
AB	A and B	None	Yes	Yes
O	None	Anti-A and Anti-B	No	No

Blood Analysis—Reference: Sinclair, Thea. "Forensic Lab Activity—Blood Analysis." *A Case of Murder: A Forensic Science Unit*, 19 April 2005 <http://accessexcellence.org/AE/ATG/data/released/0157-theasinclair/Heading5.html>.

Suggestions for Instruction

The following concepts could be developed in this section:

- ➤ blood typing
- ➤ chemical reactions

- Implement a prior knowledge strategy, such as a Concept Map or a KWL (Know, Want to Know, Learned) strategy (see *SYSTH* 9.6-9.14), to activate students' prior knowledge and recognize entry-level misconceptions.
- Once concepts have been examined in class, use a Concept Organizer Frame (see *SYSTH* 11.23-11.25) to help students develop an understanding of the concepts.

Suggested Student Activities

- Activity 1a: Blood Typing Analysis
- Activity 1b: Blood Spatter Analysis

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* *SYSTH* refers to *Senior Years Science Teachers' Handbook* (Manitoba Education and Training).

Activity 1a **Teacher Notes**

Blood Typing Analysis

Specific Learning Outcomes

SLO A1	Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.
SLO A4	Recognize that science and technology interact and evolve, often advancing one another.
SLO B3	Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.
SLO C1	Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
SLO D1	Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

The Blood Typing Analysis activity involves the study of the ABO blood groups using simulated blood and antisera. Adaptations may be made to include the Rh factor.

Setting the Crime Scene

Leave vials of simulated blood (preparation instructions follow) or blood spots/spatter (ketchup or costume blood) at the crime scene (see also Activity 1b: Blood Spatter Analysis). Blood may belong to the victim and/or suspect(s). Students may either interview subjects to determine blood types, or ask for "samples" of their blood.

To determine whether a spot is actually blood, students can first drop hydrogen peroxide on a dried smear of beef blood using a prepared microscope slide (provided by investigators from the crime scene). Students must wear gloves when handling the blood slides. Real blood bubbles when a drop of hydrogen peroxide is placed on it. This reaction is due to the presence of the enzyme catalase in mammalian blood. This test works even after the blood is dried. Note that ketchup, oil stains, coffee, and tobacco juice will not cause hydrogen peroxide to bubble, and could be used to confuse the crime scene.

Materials

- simulated A, B, AB, and O blood
- simulated anti-A and anti-B sera
- spot plate
- toothpicks
- unknown blood samples (prepared by teacher)
- blood evidence gathered at crime scene
- reagents: calcium chloride, barium chloride, sodium carbonate, ammonium carbonate

Blood typing kits may be purchased from a scientific supply company. Simulated blood and antisera may be prepared as described below:

Preparing the A, B, AB, and O Blood

To four vials, each containing 100 ml water, add the following:

- Type A — 6 g $CaCl_2$
- Type B — 2.5 g $BaCl_2$
- Type AB — 6 g $CaCl_2$ and 2.5 g $BaCl_2$
- Type O — nothing (water only)

To each solution, add about 25 ml of 25 per cent Congo Red. (This may be varied.) Prepare the unknowns and blood evidence using the same method.

Preparing the Antisera

- Anti-A — 100 ml 0.1 M $Na_2CO_3$and 1 drop of blue food colouring
- Anti-B — 100 ml 0.2 M $(NH_4)_2CO_3$ and 1 drop of yellow food colouring

Procedure

Part 1: Observing the Reactions of Known Blood Samples with Antisera

The ABO blood typing system and chemical reactions/precipitation may need to be introduced or reviewed. Students then use simulated blood and antisera (precipitation of chemical solutions) to examine the different blood types. Care must be taken to ensure that equipment is clean.

Part 2: Identifying the Blood Types of Unknown Samples (Practice)

For practice, students use the procedure from Part 1 to identify the blood types of unknown samples.

Part 3: Identifying the Blood Evidence Gathered at the Crime Scene

Students use the procedure from Part 1 to identify the blood type(s) of blood evidence gathered at the crime scene.

Activity 1a — Student Page

Blood Typing Analysis

Background

One way in which blood may be characterized is by the presence or absence of molecules located on the surfaces of the red blood cells. In the ABO blood typing group, there are two types of chemical molecules or antigens that are found on the red blood cells: A and B.

- If a red blood cell has only A antigens on it, it is type A.
- If the red blood cell has only B antigens on it, it is type B.
- If the red blood cell has both A and B antigens on it, it is type AB.
- If neither A nor B antigens are on the surface, it is type O.

Objectives

- Examine the ABO system of blood classification using simulated blood and antiserum.
- Determine the blood type of unknown blood samples.
- Determine the blood type(s) of blood evidence found at the crime scene.

Materials

- simulated A, B, AB, and O blood
- simulated anti-A and anti-B sera
- spot plate
- toothpicks
- unknown blood samples (prepared by teacher)
- blood evidence gathered at crime scene

Note: Ensure all equipment is clean and discard all used materials (such as toothpicks).

Procedure

Record your observations, results, and explorations in your *Forensic Investigation Lab Book*.

Part 1: Observing the Reactions of Known Blood Samples with Antiserum

1. Gently swirl or shake the container with blood type A to re-suspend the cells.
2. Using a clean spot plate, place three drops of blood type A into two of the wells.
3. Add three drops of anti-serum A to one well and three drops of anti-B serum to the other.
4. Gently swirl the plate or use a clean toothpick to stir the solution (30 to 60 seconds).
5. Observe carefully, looking for clumping (agglutination) around the edges.
6. Record your results in a data table.
7. Repeat Steps 1 to 6 for blood types B, AB, and O, making sure all equipment is clean prior to use.

Part 2: Identifying the Blood Types of Unknown Samples (Practice)

1. Obtain two unknown blood samples from the teacher.
2. Repeat the procedure from Part 1 with the unknowns.
3. Record your results in a data table.
4. Compare your results with those from Part 1 to identify the unknowns.
5. Check with your teacher to ensure that you have correctly identified the unknowns.

Part 3: Identifying the Blood Evidence Gathered at the Crime Scene

1. Obtain the blood sample(s) that were gathered from the crime scene.
2. Repeat the procedure from Part 1 with the evidence.
3. Record your results in a data table such as the one below.
4. Compare your results with those from Part 1 to identify the blood evidence.

Blood Typing from Evidence at Crime Scene

Blood Source	Agglutination				Blood Type
	Anti-A		Anti-B		
	Yes	No	Yes	No	
Crime Scene					
Victim					
Suspect A					
Suspect B					
Suspect C					
Suspect D					

Analysis

1. Explain how blood collected at the scene of a crime could be used in a criminal investigation.

2. Identify and describe other situations, in addition to criminal investigations, where a working knowledge of blood types and the procedure to determine blood type might be used.

Activity 1b **Teacher Notes**

Blood Spatter Analysis

Specific Learning Outcomes

SLO A2:	Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
SLO C5:	Work cooperatively with others and value their ideas and contributions.
SLO D3:	Understand the processes and conditions in which change, constancy, and equilibrium occur.

Overview

Bloodstain patterns left at crime scenes may be examined for clues as to what may have occurred during violent crimes. Forensic scientists will examine size, shape, and distribution of the blood spatter. Students will release drops of artificial blood at different heights onto sheets of paper to reproduce drops of blood from a crime scene. They will then examine the spatter from the crime scene.

Setting the Crime Scene

Leave blood spots/spatter (ketchup or costume blood) at the crime scene. Blood spatter should be consistent with the location of the injury, and the angle of spatter must be authentic, taking into consideration the height of the assailant. Blood may belong to the victim and/or suspect(s). The material on which the blood spatter is tested may be varied (for example, paper, cloth, wood, plastic, glass).

Materials

- simulated blood (see preparation instructions below)
- test tube
- dropper
- paper
- metre stick
- rulers
- ring stand

Preparation of Simulated Blood

Add together:

- corn syrup
- red food colouring
- cocoa powder
- water
- flour

Note: Vary the amount of flour and water to change the viscosity (tomato-based vegetable juice or tomato soup concentrate could also be used).

Procedure

Part 1: Comparing the Distance from which a Drop of Blood Falls to Its Diameter

Create blood with a suitable viscosity to be used consistently throughout the lab. The trial heights may be varied and decided upon by students.

Part 2: Measuring Mystery Spatter (Practice)

Prepare a number of mystery spatters ahead of time. Label or code them so that you have a record of the heights from which you dropped the blood. Students will correlate the diameter of the spatter to their baseline data and determine the approximate height from which the drop of blood fell.

Part 3: Examining Blood Spatter Evidence

Take into consideration the height and angles involved in creating the blood spatter.

Extensions

Students could calculate distance, angle, and direction from the reference point of the crime scene.

1. Calculate the direction blood travels. Lay paper on the floor (outdoors may be safer). Use a toothbrush dipped in "blood." Hold the toothbrush in hand with arm hanging freely at side and bristles pointed up to the ceiling. Quickly jerk the forearm into a right angle. Examine and describe the blood spatter.

2. Calculate the angle of impact by creating an inclined plane (on cardboard) along which a drop of blood will travel. Measure the length of elongation and the maximum width of the droplet. Repeat, varying the angle of the incline. Record and graph the data.

3. Use the blood spatter obtained in Extension 1 to determine the origin of the blood spatter. Choose five to seven teardrop-shaped droplets. Draw an extended longitudinal axis through the head and tail of each droplet using a ruler. The point of intersection of the extended lines provides a relationship that approximates the physical point of origin.

Activity 1b **Student Page**

Blood Spatter Analysis

Objectives

- Determine the relationship between the distance a drop of blood falls and the diameter of its spatter.
- Relate the results to the crime scene spatter.

Materials

- simulated blood (provided by teacher)
- test tube
- dropper
- paper
- metre sticks
- rulers
- ring stand

Procedure

Record your observations, data, and analysis in your *Forensic Investigation Lab Book*.

Part 1: Comparing the Distance from which a Drop of Blood Falls to Its Diameter

1. Place newspaper on the floor and a clean sheet of white paper on top of the newspaper.
2. Hold a dropper 10 cm above the paper and drop **one** drop of blood. Be careful that you do not get blood on yourself, or on the floor, the table, or your materials. For more accuracy, clamp the dropper to a ring stand.
3. Measure the diameter of the spatter in millimetres. Record your data in a data table (see example provided).
4. Repeat Steps 1 to 3 two more times and calculate the average diameter for a blood spatter at 10 cm.
5. Repeat this process, increasing the height from which you drop the blood each time. You may need to stand on a table or chair. The heights printed in the following table are suggestions only.
6. Graph the data.

Blood Spatter Analysis: Comparing Distance and Diameter				
Distance (cm)	Diameter (cm)			
	Trial 1	Trial 2	Trial 3	Average
10				
40				
80				
100				
150				
200				

Part 2: Measuring Mystery Spatter (Practice)

1. Obtain a mystery spatter from your teacher. Measure the diameter and determine the distance from which the blood fell by comparing the diameter to the results obtained in Part 1. Refer to your data to make this determination.

Part 3: Examining Blood Spatter Evidence

1. Analyze the blood spatter evidence obtained at the crime scene. Determine the distance (to the point of origin from which the blood fell) by comparing the diameter to the results obtained in Part 1.

Analysis

1. Describe the relationship between the distance of the fall and the diameter of a blood droplet.

2. What other observations were you able to make about blood spatter?

3. Are there sources of error that could create problems for your technique? If so, itemize these and raise these points as though you were a legal expert attempting to question blood spatter evidence.

ESSENTIAL UNDERSTANDING 2: FORENSIC ANTHROPOLOGY—BONE ANALYSIS

Teacher Background

Forensic anthropology is the study of skeletal and other human remains to identify an individual and/or to determine the circumstances involved in someone's death. Forensic anthropologists work to determine the age, sex, ancestry, stature, and unique features of a skeleton. At times, they rely on living descendants to provide information about the deceased.

Osteology (the study of bones) is very important when forensic scientists wish to identify remains at a crime scene. When forensic scientists arrive at a crime scene area, they are often faced with very badly decomposed remains, along with many other types of physical evidence.

Forensic investigators must be able to distinguish human bone from animal bone. For instance, bird bones are hollow. Because humans are bipedal (walk on two feet), our bones have unique features. The valgus knee and the femur do not line up exactly with the tibia, which helps us maintain our centre of gravity. Humans have a large calcaneus (heel bone) and a big toe bone, as we pass all our weight to our feet when walking.

The human body has 206 bones. The average male skeleton weighs about five (5) kilograms (about 11 pounds), and the average female skeleton weighs about three and one-half (3.5) kilograms (about 7.7 pounds).

Investigators can often determine the following basic identifying factors from bones:

- **Gender:** Many gender differences are visible when the skull is examined. Males have sloping foreheads, while females have straighter foreheads. Males have extreme supraorbital ridges, while females have slight ridges, with sharp orbital borders. Males have areas of pronounced muscle attachment visible on the cheek bones and large canines. Females have rounded chins, while the chins of males are more square. The male pelvis is narrower than that of the female.
- **Age:** Age may be estimated from *calcifications* (stages at which the bones are uniting), successive changes in the pelvis, evidence of bone disease such as arthritis, and the way the teeth are worn.
- **Previous trauma:** Evidence of a once broken or fractured bone indicates a previous trauma that may lead to a victim's identity through comparisons with medical records.
- **Height:** If the skeleton is incomplete, forensic scientists are able to approximate the height of an individual by measuring the length of the foot. The length of a person's foot is approximately 15 per cent of his or her height.

$$15/100 = \text{Length of Foot} / x \text{ (person's height)}$$

Formulas applied to the length of the femur, tibia, or fibula will also approximate the height. The ratio of body parts is slightly different in growing children.

Suggestions for Instruction

> The following concept may be developed in this section:
>
> ➤ characteristics of the human skeleton using ratios

- Implement a prior knowledge strategy, such as Listen-Draw-Pair-Share (see *SYSTH* 9.15-9.17), to review the structure of the human skeleton, to activate students' prior knowledge, and to recognize misconceptions.

Suggested Student Activities

- Activity 2a: Height Analysis
- A greater challenge would be to give groups of students a number of different measurements to perform, such as

  — total height

  — length of foot, ankle to hip, tibia, femur, arm (wrist to shoulder), radius, humerus, index finger

  — circumference of wrist, neck, or leg (just above the knee)

  — arm span (fingertip to fingertip)

  — width of back (shoulder to shoulder)

  Students need to determine whether any relationships exist between these measurements and whether any one measurement could allow a forensic investigator to determine the height of an individual. Height is a linear function of several bone lengths: humerus, radius, femur, and tibia. In the form of $y = m \cdot x + b$, students may use their graphing calculators to examine the relationship. Or they may use plotting software such as *Graphical Analysis 3* (Vernier Software & Technology) provided by Manitoba Education, Citizenship and Youth to all Senior Years schools through a site licence.
- Activity 2b: Searching for the Romanovs

Activity 2a **Teacher Notes**

Height Analysis

Specific Learning Outcomes

SLO C1:	Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
SLO C5:	Work cooperatively with others and value their ideas and contributions.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

Students establish a linear relationship between height and length of foot, length of humerus, and so on, and then determine the height of the individual (victim, suspect).

Setting the Crime Scene

Leave a footprint, shoe (see Essential Understanding 10: Soil Analysis), foot steps (stride), or pieces of skeleton (foot, humerus, radius, femur, tibia) at the crime scene.

Materials

- flexible measuring tape (at least 2 m length)

Procedure

Part 1: Determining the Relationship between Foot Length and Height

Students measure the length of the left foot and the height of a number of different individuals and determine the relationship between them. Alternatively, students determine the relationship between the length of the *humerus* (tibia, radius, femur) or the length of stride (distance from the back of the left heel of one footprint to the back of the heel on the next footprint) and height. **Note:** When using stride length, have students stride (walk, jog, run) over a distance of 2 to 3 m and then calculate the average length of one stride.

Part 2: Determining the Height of an Individual Based on Foot Length

Students use the data gathered in Part 1 and the relationship that was determined to estimate the height of the victim and/or suspect based on evidence from the crime scene (footprint, stride length, foot, femur, humerus, and so on).

Activity 2a **Student Page**

Height Analysis

Objectives

- Determine the relationship between the length of the foot (stride, humerus, tibia, femur, radius) and the height of an individual.
- Use this relationship to determine the height of an unknown individual (victim, suspect) based on evidence from the crime scene.

Materials

- Flexible measuring tape (at least 2 m length)

Procedure

Record your data and conclusions in your *Forensic Investigation Lab Book*.

Part 1: Determining the Relationship between Foot Length and Height

1. Student "test subjects" place the heels of their left feet against a wall. Measure the length of the left foot (from where heel touches wall to tip of toe) in centimetres. Record measurements in a data table.
2. Measure the height of each individual in centimetres. Record measurements in another column in the data table.
3. Graph your data.
4. Divide the length of the foot by the height of each individual, and multiply by 100. Record in another column in your data table.

Relationship between Foot Length and Height

Name of Individual	Foot Length (cm)	Height (cm)	Foot Length to Height Ratio X 100

Part 2: Determining the Height of an Individual Based on Foot Length

1. Using the data and conclusions from Part 1, determine the height of the victim and/or suspect based on his or her foot impression, shoe size, and/or foot bones.

Analysis

1. What conclusion(s) are you able to make about any relationship that may exist between height and foot length? For instance, what pattern do you see in the values that represent the ratio of foot length to height?

2. Test your conclusions further by measuring the length of a few more feet and predicting the height of those individuals.

Activity 2b **Teacher Notes**

Searching for the Romanovs

Specific Learning Outcomes

SLO B1:	Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.
SLO B2:	Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.
SLO C3:	Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

Students use the length of bones to determine height. Using the height and genetic similarities, they determine the identity of skeletons thought to be those of the Romanov family and servants.

Students will need to know the primary bones in the human skeleton, their articulation relationships, and some background information on genetics—chromosomes, DNA, and possible mitochondrial DNA (mtDNA).

Activity 2b Student Page

Searching for the Romanovs

Background

It is believed that shortly after the night of July 16, 1918, Czar Nicholas II, his wife Czarina Alexandra, their four daughters, Olga, Tatyana, Maria, and Anastasia, and their only son Alexei, were herded into the cellar, together with three of their servants and the family doctor Eugeny Botkin. They were all shot by a Bolshevik firing squad, although a number of the victims were allegedly stabbed to death when gunfire failed to kill them.

In 1989, a document written in 1920 was found. It described the night of the massacre and what happened to the bodies. Apparently, after the shooting occurred, some of the family and some of the servants were still alive. The executioners then stabbed those who were still breathing. The bodies were placed onto a truck with the intention of disposing of them down a mine shaft. However, the truck broke down during the trip to the mine. The Bolsheviks reportedly stripped the bodies and burned them with gasoline. To make future identification of the bones harder, they doused the bodies with sulfuric acid. The bones were thrown into a shallow pit, and the pit was filled with dirt.

The report gave clues to the location of the grave, and, in 1991, two Russians, an amateur historian and a former policeman who had turned to writing thrillers, found what they figured might be the burial site. After referring to archival materials and photographs, which gave an indication of a burial site, Gely Ryabov and Alexander Avdonin announced that they had discovered a communal grave approximately 20 miles from Ekaterinburg. Consequently, the Russian government authorized an official investigation coordinated by the Chief Forensic Medical Examiner of the Russian Federation.

The grave consisted of a shallow pit (less than a metre deep) and contained human skeletal remains. Many of the bones were badly damaged. All the skeletons showed evidence of violence prior to death or subsequent to it. For instance, some skulls had bullet entry points. Facial areas of the skulls were destroyed, rendering classical facial identification techniques difficult.

The Russians asked scientists in England to work with them to examine the bones. They speculated that newly available DNA technologies, which involve extracting tiny amounts of DNA from bone fragments and then amplifying the DNA so that there is enough material to study, might help in the identification of the bones and in determining their relations to each other. The bones were evaluated with three different DNA tests.

The first test involved identification of a gene that is found in both the X and the Y chromosomes. It is slightly different in the two and thus distinguishes male from female bones. This DNA test showed that there were five female and four male bodies in the grave.

Scientists also studied mitochondrial DNA (mtDNA), which is passed directly from mothers to their children and can be studied to show maternal lineages. The mtDNA patterns can link children to their mothers, grandmothers, and earlier generations. The mtDNA analysis showed that skeleton seven was related to the skeletons of the three children. The mtDNA from these four skeletons is also related to that of Prince Phillip, the great nephew of the Czarina.

The location of the grave, the condition of the bones, the finding of gold and platinum fillings in the teeth (only available to the rich), the relationships of the DNA samples from the grave to DNA samples from the descendants of the Imperial family, and other evidence all strengthen the case that the bones of the Romanovs had been found. The Chief Forensic Medical Examiner has requested your assistance in verifying the authenticity of the remains. It is believed that 11 individuals were killed by the Bolsheviks (the Romanov family, three servants, and their doctor).

Analyze the evidence to help determine who was buried in the grave.

Tandem Repeats in Genome

Normal genomes contain many extremely variable regions. These regions of the genome can have a specific sequence of nitrogenous bases repeated any number of times. We can often trace an individual's genetic sequence to his or her parents by comparing the number of copies of a genetic sequence in a region. For every chromosome we have, we get one copy of that chromosome from our mother and one copy from our father. Therefore, we expect that, given any two specific variable regions of the genome, one of our chromosomes will have the same number of repeats as our father and one will have the same number of repeats as our mother.

Formulas for Determining Height from Bone Length (measured in centimetres)

- Femur ➔ 2.38 (femur length) + 61.41 = height
- Humerus ➔ 3.08 (humerus length) + 70.45 = height
- Radius ➔ 3.78 (radius length) + 79.01 = height
- Tibia ➔ 2.52 (tibia length) + 78.62 = height
- Fibula ➔ 2.68 (fibula length) + 71.78 = height

Determing Height from Bone Length

Skeleton	Tandem Repeats	Femur Length (cm)	Humerus Length (cm)	Radius Length (cm)	Height (cm)	Possible Identification
1	9, 10	44.79	31.5			
2	6, 10	37.64	26.15			
3 (Child)	8, 10	38.9	27.1			
4	7, 10	42.5	30.0			
5 (Child)	7, 8	38.9	27.21	20.34		
6 (Child)	8, 10	37.6	26.2	23.0		
7	8, 8	39.4	27.40			
8	6, 9	38.32	26.68			
9	6, 6	37.32	25.92			

Analysis

1. Use the genomic evidence (tandem repeats) to determine the possible parents of the children (the Czar and Czarina).

2. Which individuals could not possibly be parents of the children? Explain.

3. Anastasia was about 164 cm (5' 4 ¾") tall. Could her skeleton be one of those found in the pit? Explain.

4. Which skeleton do you think is that of the Czar? the Czarina? Explain your reasoning.

5. Research to find more information on the discovery and analysis of the remains of the Romanov family. Who do scientists believe was actually found in the pit, according to your information sources?

ESSENTIAL UNDERSTANDING 3: CHROMATOGRAPHY

Teacher Background

Some materials appear homogenous, but are actually a combination of substances. *Chromatography* is an ancient method used to separate and identify parts of a mixture. Ink is a mixture of several colours and, therefore, can be separated using chromatography. If ink is exposed to certain liquids called solvents, the colours will dissolve and separate within the liquids. Some inks are water-soluble and some are alcohol-soluble. If the solution is then allowed to move, pulled by capillary action, through an absorbent matrix, such as chromatography paper, the different colours will create bands on the paper.

In general, more polar materials will hydrogen-bond better to the water, causing these materials to move slowly away from water-based solvents and migrate slowly up the paper. It is probably best to explain that the components of the ink that are more soluble in the chromatography solvent will move faster along the paper and thus will appear closer to the top of the paper. Components that are less soluble in the solvent will move more slowly and appear closer to the bottom of the paper. Inks of the same type will always produce the same banding pattern when this technique is used. A banding pattern of the components of the ink mixture is called a chromatogram.

Suggestions for Instruction

The following concept may be developed in this section:

➤ separation of substances through chromatography

- Review and/or introduce chromatography using a strategy such as a Word Web or a Word Cluster (see *SYSTH* 10.11-10.12) to place chromatography in context.

Suggested Student Activity

- Activity 3: The Colour of Guilt—Chromatography

Activity 3 **Teacher Notes**

The Colour of Guilt—Chromatography

Specific Learning Outcomes

SLO A5:	Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.
SLO B4:	Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.
SLO D3:	Understand the processes and conditions in which change, constancy, and equilibrium occur.

Overview

In this learning activity students use paper chromatography as a method of examining evidence from the crime scene. Students analyze the ink from different pens to observe that each has a unique chromatogram.

Setting the Crime Scene

- Leave a note written in black ink at the crime scene. The note may contain relevant information, and may also be used in other activities (see Activity 7a: Fibre and Stain Analysis and Activity 8: The Science of Handwriting Analysis?).
- Leave a smear (chromatogram) from a certain colour of candy (brightly coloured, candy-coated chocolate discs) at the crime scene (could be due to rain, a leak, and so on). Link the colour to a suspect and/or victim (for example, colour on hands, candy in pocket, favourite candy).

Materials

- chromatography paper or filter paper for chromatography
- several different black felt pens or types of black ink
- pencil
- capillary tube
- test tubes (or clear plastic cups) to hold chromatogram
- test tube rack
- paper clips
- tape
- scissors
- candy-coated chocolate discs of different colours
- wax marking pencil
- note from crime scene

- solvent (solubility of inks will vary):
  — water
  — alcohol
  — solution of rubbing alcohol, vinegar, and water
  — acetone (nail polish remover)

Procedure

Part 1: Separating Black Ink Using Chromatography

Students learn how to make a chromatogram. Using different pens with black ink, students determine that each ink has a unique chromatogram, depending on the combination of ink colours put together to make black. Use masking tape to label each pen (for example, #1 to #6).

Part 2: Examining the Mystery Note Using Chromatography

Students make a chromatogram from the ink on a note found at the crime scene and compare these results to their results in Part 1. Students must have their piece of note taped to the filter paper with the ink facing the filter paper.

Part 3: Identifying the Colours in the Candy Coating

To demonstrate that food colouring as well as ink can make a chromatogram, students can rub the coating from candies, such as candy-coated chocolate discs, onto the filter paper. The candy will have to be slightly damp so the colour from the candy can be transferred onto the filter paper.

Part 4: Determining Which Colour of Candy Was Left at the Crime Scene

Students use their results from Part 3 to examine the candy evidence from the crime scene.

Activity 3 **Student Page**

The Colour of Guilt—Chromatography

Background

Some materials appear homogenous, but are actually a combination of substances. *Chromatography* is an ancient method used to separate and identify parts of a mixture. Ink is a mixture of several colours and, therefore, can be separated using chromatography. If ink is exposed to certain liquids called solvents, the colours will dissolve and separate within the liquids. Some inks are water-soluble and some are alcohol-soluble. If the solution is then allowed to move, pulled by capillary action, through an absorbent matrix, such as chromatography paper, the different colours will create bands on the paper.

Objectives

- Use chromatography to determine the colour composition of various black inks.
- Use chromatography to identify the black pen used to write a note found at a crime scene.
- Use chromatography to identify the colours used in the coating of candy-coated chocolate discs.

Materials

- chromatography paper or filter paper for chromatography
- several different black felt pens or types of black ink
- pencil
- capillary tube
- test tubes (or clear plastic cups) to hold chromatogram
- test tube rack
- paper clips
- tape
- scissors
- candy-coated chocolate discs of different colours
- wax marking pencil
- note from crime scene
- solvent (solubility of inks will vary):
  - — water
  - — alcohol
  - — solution of rubbing alcohol, vinegar, and water
  - — acetone (nail polish remover)

Procedure

Record your work in your *Forensic Investigation Lab Book*.

Part 1: Separating Black Ink Using Chromatography

1. Cut strips of chromatography (filter) paper approximately 17 cm long and 1.5 cm wide (one strip per pen to be tested). Strips should fit into a test tube without touching sides. Test the fit in a dry test tube before adding solvent.
2. Cut one end of each strip into a point. This tip will touch the solvent.
3. Use a capillary tube to place a black dot (about 2 cm up from the pointed end of the strip) from each ink type on the strips (one per type of black ink). Make sure you label each strip or chromatogram with a pencil so you can tell them apart.
4. Place a small amount of water (or other solvent) at the bottom of each test tube.
5. Loop the top of the filter paper over a pencil or attach it to a paper clip suspended across the top of the test tube.
6. Hang the strip of paper into the test tube, with the tip just touching the solvent. Do not let the dot go below the solvent level.
7. Allow the solvent to soak up the strip and watch what happens to the ink. Wait until the solvent no longer appears to be separating the ink. This may take 30 to 60 minutes. Take the strips out of the test tubes and let them dry. Once dry, relabel your strips, and tape them into your *Forensic Investigation Lab Book*. Your results will be used in Part 2.

Part 2: Examining the Mystery Note Using Chromatography

1. Cut out an individual letter from the mystery note provided and tape it to the filter paper with the ink facing the filter paper.
2. Run the chromatography experiment (see Part 1) and tape the chromatogram to your *Forensic Investigation Lab Book*. Compare the chromatograms of the ink you tested to the chromatogram of the mystery note from the crime scene. Record which type of ink was used to write the note. What specific evidence enabled you to come to this conclusion?

Part 3: Identifying the Colours in the Candy Coating

1. Make chromatogram strips (one per candy) and collect candy-coated discs of different colours. Using a pencil, record the colour of each candy on a chromatogram strip.
2. Wet the edge of the candy with a very small drop of water and rub its edge on a chromatography strip until the colour is gone from the edge of the candy. Repeat this procedure by placing a drop of water on the top of the candy and rotating that surface to make a distinct dot on the chromatogram. The dot should be at approximately the same spot as the pen dot in Part 1.
3. Repeat the last procedure with the other candies on the other chromatogram strips.
4. Run the chromatography experiment as described in Part 1 and observe the patterns produced on the strips.

5. Attach the strips to your *Forensic Investigation Lab Book*. Below each strip, identify the colours used to make the candy coating.

Part 4: Determining Which Colour of Candy Was Left at the Crime Scene

1. Use the data gathered in Part 3 to examine the candy evidence from the crime scene (for example, colour smear on hand or clothes, candy in pocket of victim or suspect).

Analysis

1. Explain how to construct a *chromatogram*.

2. Explain how *chromatography* can be used to separate and identify different substances that appear to look the same.

3. Describe how chromatography could be used to assist in solving a crime.

4. What are some possible sources of error in this chromatography experiment? Explain.

ESSENTIAL UNDERSTANDING 4: DECOMPOSITION

Teacher Background

Establishing the time of death is difficult and often involves a combination of factors, including witness interviews. Forensic investigators will also examine the following:

- Body temperature may be affected by environmental conditions, layers of body fat, amount of clothing, and drugs. A decrease in body temperature *post-mortem* (after death) is proportional to the ambient environment temperature. Typically, a body cools one to one and a half degrees Celsius per hour until it reaches environmental temperature. Review Newton's Law of Cooling.
- Post-mortem lividity or *livor mortis* (discolouration) occurs when the blood settles to the lowest parts of the body due to gravity. The discolouration appears one to two hours after death and becomes fixed within eight to 10 hours.
- *Rigor mortis*, which is the stiffening of muscles, starts as early as 15 minutes after death and lasts as long as 36 hours.
- Clouding of the eye due to potassium buildup occurs within two to three hours if the eyes are open, and 24 hours if the eyes are closed.
- The rate of food digestion, which ranges between four and six hours, may be affected by type of food, metabolic rate, drugs, emotional condition, and exercise.
- Decay and decomposition rates depend on various factors, such as weather, environment, and scavengers.

Forensic scientists must be experts on decomposition and must study rotting corpses to help police solve cases. The stages of decomposition are: paling of the skin, flattening of the eyes, blue colouration of the extremities, desiccation of mucous membranes, putrefaction of the body (swelling and rotting as bacteria proliferate), blackening of the skin, bloating, blistering, and peeling of the skin, liquefaction of organs, and loosening of teeth, hair, and nails. Temperature will affect the rate of decomposition, as will exposure to the environment and scavengers. Even the smell of putrefaction and amount of bloating follow a specific cycle, and can help in estimating the time of death. Under warm and humid conditions, a body can decompose into a skeleton within a few weeks; while in other conditions, it may take much longer, even years. In a hot, dry, and arid environment, a body might mummify. Forensic scientists have established "body farms" to study in detail the processes of decomposition.

Decomposition—Reference: Staerkeby, Marten. "Establishing Time of Death with Forensic Entomology." *The Ultimate Guide to Forensic Entomology*, 18 April 2005 <http://folk.uio.no/mostarke/forens_ent/forensic_entomology.html>.

Arthropods are often the first to encounter a corpse. This involves the study of entomology, as the appearance of bugs on, in, around, and under the corpse gives many clues to the timing and location of death. As the carcass decays, it attracts various insect species. Insects arrive in stages, and as each group feeds on the body, it changes the body for the next group. The blowflies usually are the first to arrive, within minutes. They lay their eggs, which hatch into maggots that feed on the decaying tissue. Other insects feed on the body at varying stages as it ferments. *Necrophagous species* (flies and beetles) feed directly on the corpse for about the first two weeks. Predators and parasites of the flies, and beetles and wasps that prey on eggs and maggots may arrive next. Spiders may also use the body as a habitat to prey on other insects. By observing which species are present and what stage of development they have reached (egg, larva, pupa, or adult) and comparing that information to local weather data, scientists are able to establish a chronology of death. Small things such as insect larval stage and pupal casings observed in a crime scene photograph can narrow down the time of death and help police gain a conviction. Forensic entomologists might even examine the gut contents of insects to establish what a person ingested or to obtain DNA materials.

Suggestions for Instruction

The following concepts may be developed in this section:

- ➤ the life cycle of insects
- ➤ decomposition

- Use a Concept Map (see *SYSTH* 9.6-9.7) to establish the relationships within decomposition.
- Students research the use of entomology in forensic sciences (see *SYSTH*, Chapter 14: Technical Writing in Science).

Suggested Student Activities

- Activity 4a: Forensic Entomology Research Assignment
- Activity 4b: A Bug’s Tale
- As part of Activity 4b, students write a Forensic Entomology Report detailing the entomological evidence from the crime scene or released to student project teams for analysis and conclusions.
- Students could also research mummies, the mummification process (for example, Tollund Man, Lindow Man, Yde Girl, Cherchen, Tarim Basin, Takla Makan, Lemon Grove, Chiribaya, Chinchorro, Chachapoya, Guanche, Egyptian kings [Tutankhamun, Ramses II “the Great”]), or instances of remaining “incorrupt” (no signs of decay) many years after death (for example, Bernadette Soubirous of France—19th century).

Activity 4a **Teacher Notes**

Forensic Entomology Research Assignment

Specific Learning Outcomes

SLO B4:	Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.
SLO C4:	Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.
SLO D2:	Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.
SLO D4:	Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

Overview

Students research the use of entomology in forensics and the role of an entomologist on a forensic investigative team.

In preparation for the research assignment and report, review the following with students:

- the fundamentals of technical writing (see *SYSTH*, Chapter 14)
- how to find and record information (see *SYSTH* 14.15)
- the main components of a research paper (see *SYSTH* 14.10)

Activity 4a

Student Page

Forensic Entomology Research Assignment

Research Notes

Topic: ______________________________

Research Questions:

1. ______________________________

____

2. ______________________________

____

3. ______________________________

____

4. ______________________________

____

Resource Type(s): ______________________________

Reference(s): ______________________________

Answers to Questions:

1. ______________________________

____

____

2. ______________________________

____

____

3. ______________________________

____

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4. ______________________________

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Activity 4b **Teacher Notes**

A Bug's Tale

Background

Insects arrive on a body shortly after death, allowing forensic entomologists to gather information to estimate the time of death (post-mortem interval). The succession of different species on cadavers happens in a fairly predictable sequence, depending on the state of the body and the part of the body exposed. For example, beetles feeding on bone will only arrive when bone becomes accessible.

Insect life cycles follow predictable patterns (see table below), and determining the stages of life cycles is critical in an investigation. To establish baseline times for the life cycles, forensic entomologists may rear blowflies discovered at the scene under temperature and humidity conditions similar to those to which the body was exposed. They are then able to compare the life cycle stage of the insects gathered as evidence to this baseline data and estimate a time of death. Life cycles are dependent on species, temperature, and humidity. If the death occurred in the winter, investigation becomes difficult, as few insects are active in the winter.

Life Cycle of Blowflies

Genus: *Diptera*

Species: *Calliphoridae* or "Blowflies"

Life Cycle Stage	Timing	Description	Observations
Eggs	1 day	2 mm	Located especially around the body's natural orifices, such as the nose, eyes, ears, anus, penis, vagina, and in any wounds.
Larvae — First Instar	1.8 days	5 mm	
Larvae — Second Instar	2.5 days	10 mm	
Larvae — Third Instar	4-5 days	17 mm	
Prepupae	8-12 days	12 mm	Larvae become restless and start to move away from the body, crop organ is gradually emptied of blood, and internal features are gradually obscured by the larvae's enlarged body.
Pupae	18-24 days	9 mm Darkens with age	Presence of empty puparia an indication that the person in question has been dead approximately 20 days.

A Bug's Tale—Reference: Staerkeby, Marten. "Establishing Time of Death with Forensic Entomology." *The Ultimate Guide to Forensic Entomology*, 18 April 2005 <http://folk.uio.no/mostarke/forens_ent/forensic_entomology.html>.

Activity 4b

Student Page

A Bug's Tale

A forensic entomologist made the following observations about the crime scene. Read the description and construct a data table in your *Forensic Investigation Lab Book*. Include the type of insect, time of arrival, time of departure, and the inferences you might make from this information. Explain when the victim probably died and how you determined the time of death.

Forensic Entomologist's Report

Observations about Crime Scene

The body was bloated and swollen, in the beginning stages of putrefaction. The body temperature was 10 degrees Celsius at the scene. The ambient temperature was 9 degrees Celsius. Second instar maggots were obvious in all orifices. Rove beetles and other parasites were also present.

Analysis

1. Using the forensic entomologists' observations about the crime scene, construct a data table that captures the following information.

Data Table

Type of Insect	Time of Arrival	Time of Departure	Inferences

2. Approximately *when* did the victim die?

3. How do you know this?

Activity 4b

Student Page

Student's Forensic Entomology Report

Date: ____________________ Case Number: ____________________

Forensic Entomologist: ______________________________________

Location Description

Recent Meteorology (Last Seven Days):

Temperature Conditions: ______________________________________

Precipitation Patterns: ______________________________________

Humidity Conditions: ______________________________________

Resting Place:

Urban Setting: ❑ Enclosed Building ❑ Vacant Building ❑ Vacant Lot

❑ Garbage Container ❑ Other ____________________

Rural Setting: ❑ Open Field ❑ Vegetation (type of vegetation) ____________

❑ Forest ❑ Roadside Ditch ❑ Bare Ground

Current Temperatures:

Ambient (air): ____________________ Body: ____________________

Soil (depth): ____________________ Water: ____________________

Description of Remains

Approximate Age: ____________________ Sex: ____________________

Date and Time Found: ______________________________________

Clothing: ______________________________________

____

Wounds on Body? ❑ Yes ❑ No

Type: ____________ Where: ____________________

Body Position: ______________________________________

Exposure of Body: ❑ Full Sun ❑ Shaded Area

❑ Part Sun Portion of Day (%) ____________

(continued)

Description of Remains (*continued*)

Stage of Decomposition:
- ❑ Initial (Stage 1)
- ❑ Putrefaction (Stage 2)
- ❑ Advanced Putrefaction (Stage 3)
- ❑ Butyric (Stage 4)
- ❑ Dry Decay (Stage 5)

Evidence of Insect Scavengers:

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Further Comments:

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ESSENTIAL UNDERSTANDING 5: DNA PROFILING

Teacher Background

The Structure and Function of DNA

DNA (deoxyribonucleic acid) is found in almost every living thing. An organism is composed of thousands of tiny cells, most of which contain long, string-like DNA tightly folded into chromosomes within a nucleus. If uncoiled, the DNA molecules in a human cell would measure almost two metres in length. That is the total length of the 3.3 billion base pairs that make up the total human genetic complement, or genome, found in virtually every cell. Except for identical twins, the sequence of the base pairs within the DNA helix is unique for every person, and forms the individual's genetic code or blueprint. The growth and development of an organism is governed by instructions encoded within the DNA molecule.

In humans, each parent contributes one chromosome to each of the 23 pairs found in all normal people. Genes are the fundamental unit of heredity and are sections of DNA coding for the growth and development of the organism. Thousands of genes are located on the chromosomes. Each gene can have different versions called alleles. Genes determine all inherited traits, including those that give the individual specific characteristics (such as eye colour) as well as common characteristics (such as the structure of the heart).

The DNA polymer is a long, double-stranded string of repeating units called bases or nucleotides: adenine (A), cytosine (C), guanine (G), and thymine (T). This sequence of letters makes up the genetic code and determines which characteristics will be expressed by a particular gene. Cutting all the sentences out of 40 volumes of encyclopedias and taping them end to end would represent the amount of information contained within the DNA of each of our cells.

In the two strands, A pairs with T and G with C. These pairings are what connect the two strands of DNA together to form a tightly coiled, twisted ladder. This spiral staircase, the famous double helix, is the natural form in which DNA is found within the nucleus of the cells.

The DNA and, hence, the genetic code of humans is almost the same for all individuals. It is the very small amount that differs from person to person that forensic scientists analyze to identify people. These differences are called polymorphisms and are the key to DNA typing. Polymorphisms may include variations in the length of repeating sequences or a difference between alleles or specific nucleotides. When several different sequences are considered, the chances that any two individuals will have exactly the same variation are very remote.

Forensic DNA Testing (DNA Fingerprinting)

Forensic investigators commonly look for DNA in specimens of blood, semen, body tissues, hair (especially roots), and saliva (for example, envelope flaps, stamps, cigarette butts, cups, telephones, bite marks). Collection of usable evidence depends on the location (type of surface or substrate) of the sample, contamination, age (survival is low in soft tissues such as liver and kidney, longer in muscle and brain, and longest in dense bone and teeth).

Exemplars or specimens drawn from suspects or victims are usually liquid blood or sometimes buccal (inside cheek) swabs.

Minute amounts of DNA evidence gathered from a crime scene may be analyzed and compared to reference samples. Procedures are limited by quantity, contamination, and amount of degradation. DNA is degraded by things such as warmth and age. Scientists are continually improving forensic testing methods.

Initially, scientists must remove the DNA sample from its location (for example, clothing), and then purify it through extraction and precipitation. Detergent is used to destroy the integrity of the cell and nuclear membranes, which releases the DNA, and proteins attached to the DNA are digested by enzymes. Small quantities of DNA may be amplified through PCR (polymerase chain reaction).

The DNA is cut into different-sized fragments using restriction enzymes (chemical scissors) that recognize specific DNA sequences. The DNA sample, containing a variety of fragment sizes, is then placed at one end of a gel. Electrophoresis gels have several lanes, including marker lanes that measure how far fragments move through the gel and a lane for control DNA that produces a known pattern and can be used to verify that the test was properly conducted. The DNA in the gel can be stained and seen under ultraviolet (black) light. An electric current is used to pull the negatively charged DNA fragments through the gel toward the positive pole. The gel contains pores or holes, through which the DNA moves. The smaller fragments move more rapidly, and the relative position of the fragments within the gel is determined by their length or their molecular weight. A radioactive DNA probe binds to and illuminates the DNA samples, and a picture or blot may be made.

Interpretation of Forensic DNA Analysis Data

A comparison of DNA ladders may be made by examining the number and location of bands of DNA between samples. A match may be declared if two samples have RFLP (restriction fragment length polymorphism) band sizes that are all within 5 per cent of one another. The suspect can then be included in the group of individuals who were at the crime scene. If no match occurs, the suspect could not have been the source of evidence and is excluded. The data may be inconclusive, which often occurs when the DNA is old and heavily contaminated.

Forensic scientists apply population frequency statistics, based on the probability of a genetic profile occurring, to determine the chance that two samples are identical or do not match. This is a contentious issue, and other facts must also be considered when examining genetic evidence. For example, the genetic profile from the blood at a crime scene may match that of a suspect, with a pair of matching profiles found in one in 200 individuals. It appears that there is a high probability that the blood came from someone else. Scientists must then take other factors into consideration, such as the probability that the suspect was at the crime scene versus one of the other members of the population with the same genetic blood profile. Because of the complexities of populations, databases must be interpreted with extreme care. For example, DNA fragment sizes rare in one population may be more common in other populations. Further sub-populations or populations within populations must be considered.

Suggestions for Instruction

The following concepts may be developed in this section:

- ➤ the structure and function of DNA
- ➤ DNA fingerprinting
- ➤ population genetics

- Develop a DNA Concept Map, KWL chart, or Listen-Draw-Pair-Share strategy (see *SYSTH* 9.6-9.17) to activate and organize students' prior knowledge.
- Use a Concept Organizer Frame (see *SYSTH* 11.23-11.25) to organize conceptual knowledge after instruction.

Suggested Student Activities

- Activity 5a: Extracting DNA from Onion Cells
- Activity 5b: DNA Fingerprinting—Bar Code Simulation
- Activity 5c: DNA Fingerprinting—Electrophoresis
- Students research applications of DNA fingerprinting and issues that may arise. Examples include paternity testing, proof of wrongful convictions, insurance requirements, DNA criminal databases, and so on.

Activity 5a **Teacher Notes**

Extracting DNA from Onion Cells

Specific Learning Outcomes

SLO B1:	Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.
SLO C1:	Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
SLO C5:	Work cooperatively with others and value their ideas and contributions.
SLO D2:	Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.
SLO D4:	Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

Overview

Isolating DNA from cells is an important first step in doing DNA analysis. This procedure is used to extract large amounts of DNA from onions, and similar protocols are used to isolate DNA from other sources, such as liver tissue or peas. Students will learn how familiar chemicals are used to purify DNA.

Materials

- chopped onion
- mortar and pestle or blender (optional)
- large test tube
- cheesecloth
- funnel
- 500 ml beaker (hot water bath)
- ice bath
- ice-cold (chilled) 50 per cent ethanol
- wooden stick (skewer)
- detergent solution (1 part table salt + 1 part liquid soap/shampoo + 8 parts water)
- enzyme solution (1 part meat tenderizer + 19 parts water)

Extracting DNA from Onion Cells: Adapted from Northern Arizona University. Science & Technology Resources: <http://jan.ucc.nau.edu/~lrm22/lessons/dna_extraction/dna_extraction.html>. Adapted by permission.

Activity 5a Student Page

Extracting DNA from Onion Cells

Overview

Isolating DNA from cells is an important first step in doing DNA analysis. This procedure is used to extract large amounts of DNA from onions, and similar protocols are used to isolate DNA from other sources, such as liver tissue or peas. You will learn how familiar chemicals are used to purify DNA.

Objectives

- Mechanically and chemically break down onion tissue to allow DNA to be extracted from the nucleus of plant cells.
- Use a process to allow nuclear material to be collected.

Materials

- chopped onion
- mortar and pestle or blender (optional)
- large test tube
- cheesecloth
- funnel
- 500 ml beaker (hot water bath)
- ice bath
- ice-cold (chilled) 50 per cent ethanol
- wooden stick (skewer)
- detergent solution (1 part table salt + 1 part liquid soap/shampoo + 8 parts water)
- enzyme solution (1 part meat tenderizer + 19 parts water)

Procedure

1. Chop about 10 ml of onion into tiny pieces. *This causes physical disruption of the cell walls*.
2. Place chopped onion in the mortar and grind with the pestle. *This continues the physical breakdown of the cell walls, allowing the cytoplasm to leak out*.
3. Add about 10 ml of detergent solution and grind again (a blender may be used). *The detergent breaks down the lipids in the phospholipid bilayers of the cell and nuclear membranes. This process allows DNA to be released from the nucleus and allows nuclear material to be released from the cell*.

Extracting DNA from Onion Cells: Adapted from Northern Arizona University. Science & Technology Resources: <http://jan.ucc.nau.edu/~lrm22/lessons/dna_extraction/dna_extraction.html>. Adapted by permission.

4. Filter the mixture into a large test tube through cheesecloth placed in a funnel. *This allows the unwanted, large cellular material to be separated from the smaller DNA*. **Note:** To avoid breaking the fragile DNA strands, do not agitate from this point on.

5. Add about 3 to 4 ml of the enzyme solution to the test tube. *This causes the DNA to uncoil by denaturing (breaking down) the histone proteins that are keeping the DNA tightly coiled into chromosomes*.

6. Stand the test tube with the mixture in a beaker of hot tap water for 10 minutes. *Heat increases the rate of chemical reactions and speeds up the action of the enzymes.*

7. Place the test tube in the ice bath for 3 to 5 minutes. *Cooling decreases the rate of chemical reactions, slowing the action of the enzymes before they destroy the DNA*.

8. Carefully pour 10 ml of ice-cold ethanol into the test tube to form a separate layer on top. Wisps of gel should form where the two layers meet. *The polar/non-polar division between layers causes the DNA to precipitate.*

9. Use a stick gently to wind up the precipitated DNA. It should look like white mucus.

Analysis

1. Is the substance obtained at the end pure DNA? Explain.

2. Where might errors occur in the procedure?

3. How might the process of DNA extraction be useful to forensic investigators?

4. Where else might the process of DNA extraction be used?

Activity 5b **Teacher Notes**

DNA Fingerprinting—Bar Code Simulation

Student Learning Outcomes

SLO A2:	Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
SLO B2:	Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.
SLO B4:	Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.
SLO C3:	Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Background

DNA fingerprinting may be familiar to many students since many television shows, movies, and books now refer to the procedure. The purpose of this learning activity is to introduce students to the process of DNA fingerprinting using bar codes. It is not intended to be an exhaustive study of DNA analysis, but rather an activity that models the procedure and provides students with a greater appreciation for the process. Use your discretion in the amount and level of detail you wish to use to describe DNA.

This learning activity assumes that students realize that DNA is genetic material responsible for the uniqueness of each person. Each person's DNA is uniquely different from everyone else's. Restriction enzymes (proteins) can be added to DNA samples that will "cut" the DNA whenever a specific sequence is present. Since everyone's DNA sequence is unique, the pattern of cut DNA will also be unique.

Setting the Crime Scene

Leave a DNA sample (bar code) at the crime scene. You may choose to establish where the DNA came from: blood, skin, hair, saliva, and so on. You may also choose to leave more than one type of DNA evidence and/or connect this evidence to more than one person.

The DNA fingerprinting lab uses bar codes as a model for the electrophoresis gel used in scientific laboratories (which is also used in Activity 5c to do DNA analysis). It is important for students to realize that each person has a unique bar code or DNA profile. Their task in this activity is to match a specific DNA profile to a list of collected DNA profiles. This activity provides an opportunity to focus on specific data-collecting skills students need to develop. For example, if they are to develop appropriate lab notes for use in their assessment tasks, this is a good lab for having students collect and present their results.

This activity is not complicated, but it does require you to make a page of bar codes. Some samples are provided (see Student Page for Activity 5b). Each bar code should be numbered so that a match can be made. Students will compare the DNA evidence gathered at the crime scene to the known DNA samples from the suspects and victim(s).

Materials

- set of bar codes (copy from products or cut out of attached Student Page) labelled with suspects' codes/names
- DNA evidence sample (bar code) on clear acetate (should match with one from suspects)

Activity 5b **Student Page**

DNA Fingerprinting—Bar Code Simulation

Objectives

- Use bar codes to identify a DNA sample.
- Determine whether DNA fingerprinting is an effective method for identifying a specific person.

Materials

- bar code samples
- DNA evidence sample (bar code) on acetate (crime scene evidence)

Procedure

1. Examine the file of DNA codes obtained from the victim and/or suspects.
2. Compare these to the DNA fingerprint(s) obtained from the crime scene.
3. Record your observations in your *Forensic Investigation Lab Book*.

Analysis

Record your analysis in your *Forensic Investigation Lab Book.*

1. What is DNA and where is it found?

2. How does DNA fingerprinting allow forensic investigators to identify a particular individual?

3. Record your conclusion(s).

4. Explain how you arrived at your conclusion(s).

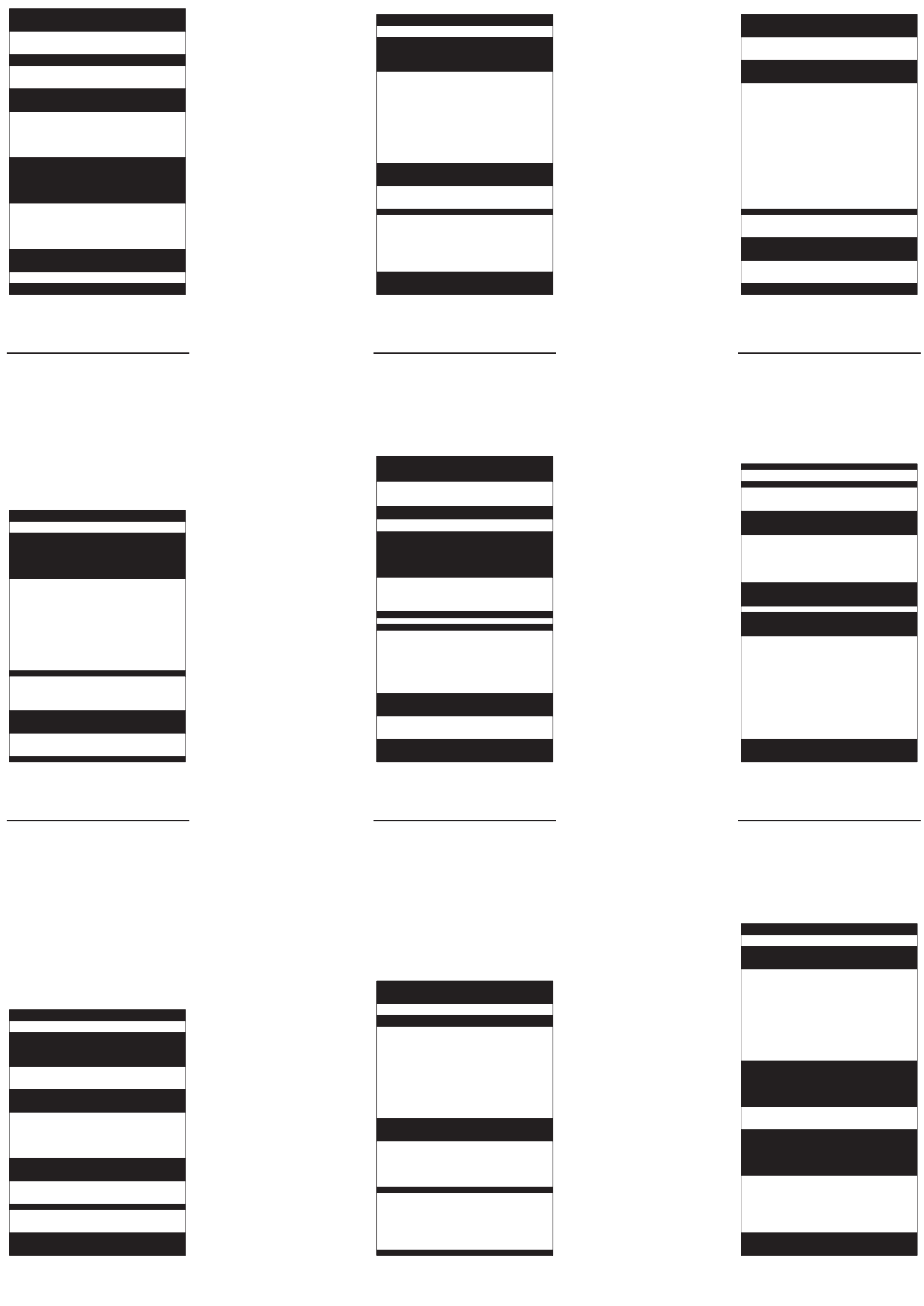
5. Develop a hypothetical scenario to explain your observations.

6. Identify some possible concerns associated with DNA fingerprinting.

Activity 5b

Student Page

DNA Analysis—Sample Bar Codes



Activity 5c **Teacher Notes**

DNA Fingerprinting—Electrophoresis

Student Learning Outcomes

SLO A1:	Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.
SLO A4:	Recognize that science and technology interact and evolve, often advancing one another.
SLO A5:	Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.
SLO B1:	Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.
SLO C3:	Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.
SLO D3:	Understand the processes and conditions in which change, constancy, and equilibrium occur.

Background

DNA fingerprinting may be familiar to many students, as many television shows, movies, and books refer to the procedure. The purpose of this learning activity is to introduce students to the process of DNA fingerprinting using electrophoresis.

Each person's DNA is uniquely different from everyone else's. Restriction enzymes (proteins) can be added to DNA samples, which will "cut" the DNA whenever a specific sequence is present in the DNA. Since everyone's DNA sequence is unique, the pattern of cut DNA will also be unique.

Setting the Crime Scene

Place a small sample of DNA evidence at the crime scene or provide students with a sample. Students will run an electrophoresis separation with the "suspect's" DNA, and compare with sample from crime scene. You may choose to establish where the DNA came from: blood, skin, hair, saliva, and so on. You may also choose to leave more than one type of DNA evidence and/or connect this evidence to more than one person.

It is important for students to realize that each person has a DNA profile. Their task in this activity is to match a specific DNA profile to a list of collected DNA profiles.

Materials

- Various electrophoresis kits and apparatus are available from scientific supply companies.
  — Example: *PCR Forensics Simulation Kit* (from a biological supply company)
- Use different DNA samples or ink samples to link to various individuals.

Activity 5c **Student Page**

DNA Fingerprinting—Electrophoresis

Background

DNA analysis is a complicated process involving several steps. First, the DNA is removed from the cell nucleus, after which the DNA strands are separated from the rest of the cell parts and chopped into smaller pieces. Then, human DNA pieces are combined with radioactive DNA. (The scientist will be able to track the pieces of human DNA later.) The DNA pieces are separated from one another into bands according to size, using gel electrophoresis. This process is similar to chromatography. Pictures are taken of the separated DNA pieces to record the individual's DNA profile.

Objectives

- Use electrophoresis to separate DNA fragments.
- Create DNA fingerprints and compare them to known samples to establish an identity.
- Determine whether DNA fingerprinting is an effective method of identifying a specific person.

Materials

- electrophoresis apparatus (provided by teacher)

Procedure

1. Ensure that both ends of the gel electrophoresis chamber are sealed.
2. Prepare a 1 per cent agarose gel solution and heat it briefly until it melts.
3. Pour the agarose gel into the gel electrophoresis chamber. Place the comb into the agarose mixture to create wells for the DNA and allow the mixture to harden.
4. When the agarose is solid, cover it with TBE electrophoresis buffer, ensuring that the gel is submerged. Carefully remove the comb.
5. Carefully load DNA samples that have been cut with restriction enzymes into the different wells, using a clean pipette each time.
6. Put the lid on the gel chamber. Be sure the wells are at the negative electrode. Plug the leads into the 120V power supply and run the electrophoresis until the fragments have separated. Depending on the power supply, you may have to ask your teacher to turn off the power later in the day or the next morning.
7. If required, visualize the bands by placing the gel carefully in methylene blue stain. Let the stain set for 30 minutes, and then remove the gel while wearing gloves on your hands. Place the gel in distilled water for de-staining, rinsing several times. Finally, set the gel on the white light source and compare the bands.
8. Measure and draw the DNA banding patterns exactly as they appear on the gel. Record your work in your *Forensic Investigation Lab Book*.

Analysis

Record your analysis in your *Forensic Investigation Lab Book.*

1. What is DNA and where is it found?

2. How does DNA fingerprinting allow forensic investigators to identify a particular individual?

3. Record your conclusion(s).

4. Explain how you arrived at your conclusion(s).

5. Develop a hypothetical scenario to explain your observations.

6. Identify some possible concerns associated with DNA fingerprinting.

ESSENTIAL UNDERSTANDING 6: FINGERPRINTING (DACTYLOSCOPY)

Teacher Background

Almost every time you touch something, you leave a fingerprint. Fingerprints are impressions that are created by ridges on the skin. When a person touches an object, the perspiration, oils, dirt, and amino acids on the skin stick to the surface of the object, leaving an imprint of your fingertips. Prints that you can see with the unaided eye are called visible prints. Invisible prints are called latent prints, and they are the most common. A third type of print is a plastic print. This print is an impression on objects such as soap or clay. A forensic scientist is interested in fingerprints as a means of identification to help solve crimes. *Dactyloscopy* is a technique used to compare fingerprints for identification.

Fingerprints have been used as a means of identification for centuries. In ancient Babylon, fingerprints were used on clay tablets for business transactions, and in ancient China, thumb prints have been found on clay seals. In 1000, a Roman attorney showed that a palm print was used to frame someone for murder. In 1892, Francis Galton published a book describing his method of classifying fingerprints. In 1911, the first criminal conviction based on fingerprint evidence occurred. Thomas Jennings was charged and convicted of the murder of Charles Hiller, who died during a burglary in 1910.

A fingerprint is an individual characteristic. No two identical fingerprints have been taken from different individuals, not even from identical twins. A fingerprint will remain unchanged during an individual's lifetime. Injuries such as burns or scrapes will not change the ridge structure; when new skin grows in, the same pattern will come back. Fingerprints have general characteristic ridge patterns that permit them to be systematically classified. The individuality of any fingerprint is based upon its ridge structure and specific characteristics. The specific characteristics of individual fingerprints used for identification are the number of ridges and their approximate location. The average fingerprint has 150 individual ridge characteristics. A match is assumed if between 10 and 16 specific points of reference correspond exactly.

Fingerprinting: Adapted from Mrs. Seagraves' QUEST Class and Thematic Units. Forensic Science Activities: <http://www.geocities.com/Athens/Atrium/5924/forensicscienceactivities.htm>.

Types of Fingerprints

There are three basic types of fingerprints: the *arch*, the *loop* and the *whorl*.

Plain Arch

Arches are formed by ridges running from one side to the other and curving up in the middle. Tented arches have a spike effect.

Loop

Loops have a stronger curve than arches, and the ends exit and enter the print on the same side. Radial loops slant toward the thumb, and ulnar loops slant toward the other side.

Plain Whorl

Whorls are complete ovals, often formed in a spiral pattern around a central point. There are plain whorls and central pocket loop whorls.

Composite patterns are a mix of two of the previous patterns, while accidental patterns are irregular.

Suggestions for Instruction

The following concept may be developed in this section:

➤ classification based on similarities and differences

- Use an activating prior knowledge strategy (see Appendix 2) to establish what students know about fingerprinting.
- Have students make and classify a number of fingerprints within the classroom. They may then practise trying to identify each other based on fingerprints.

Suggested Student Activities

- Activity 6: Fingerprinting
- Students debate whether fingerprinting is a science (see *SYSTH* 4.19-4.21).

Activity 6 **Teacher Notes**

Fingerprinting

Specific Learning Outcomes

SLO A1:	Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.
SLO A3:	Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

The intent of this learning activity is to have students gather fingerprint evidence at the crime scene. They will also learn how to make a fingerprint and classify fingerprints based on the pattern on the print.

Setting the Crime Scene

In setting fingerprints at the crime scene, have the suspect rub his or her finger across the bridge of the nose, across the temples, or through the hair (to gather oils). Then have the suspect press firmly with finger(s) on a clean glass or clear plastic cup without smudging, and leave this piece of evidence at the scene. A partial print will make the investigation more interesting. The print should be faintly visible.

Recording and Classifying Fingerprints

The use of ink from a pad (though it can be messy and difficult to clean off hands) is the simplest method for making fingerprints. The finger is covered with ink and then firmly rolled on a white piece of paper or a blank index card.

Another way to record fingerprints is to have students rub a pencil on a small area of a piece of paper, and then rub their fingers over the graphite. Next, have them place a piece of tape on their fingers, lift, and place the tape on a clean sheet of white paper or a blank index card. The tape may also be placed on an overhead and the fingerprint projected for the class to analyze.

Label the fingerprint to identify the individual's name, hand, and finger.

Simplify the classification of fingerprints by using three major categories: loop, arch, and whorl. Using these categories, students should be able to identify their fingerprints.
Note: Getting good results from dusting for fingerprints can be challenging, and may require plenty of practice.

Fingerprinting: Adapted from Mrs. Seagraves' QUEST Class and Thematic Units. Forensic Science Activities: <http://www.geocities.com/Athens/Atrium/5924/forensicscienceactivities.htm>. Copyright © 1999-2001 by S. Seagraves. Adapted by permission.

Materials (depending on choice of activities and/or methods)

- cocoa (light surface) or talcum powder (dark surface)
- stamp pads (washable ink)
- glasses or plastic cups (or other surface) for fingerprints
- small soft brush (soft camel hair or fibreglass)
- superglue (the larger tubes work better than the tiny tubes)
- zippered plastic evidence bag (large enough for the object with the fingerprints)
- magnifying glass
- construction paper
- white paper
- transparent tape
- index cards

Activity 6 **Student Page**

Fingerprinting

Objectives

- Collect fingerprints from the crime scene.
- Classify fingerprints according to the patterns of loop, arch, and whorl.
- Use this fingerprint classification system to match an unknown fingerprint from known samples.

Materials (depending on choice of activities and/or methods)

- cocoa (light surface) or talcum powder (dark surface)
- stamp pads (washable ink)
- glasses or plastic cups (or other surface) for fingerprints
- small soft brush (soft camel hair or fibreglass)
- superglue (the larger tubes work better than the tiny tubes)
- zippered plastic evidence bag (large enough for the object with the fingerprints)
- magnifying glass
- construction paper
- white paper
- transparent tape
- index cards

Procedure

Take a magnifying glass and study the patterns on your fingers. What do you notice? Are the patterns the same on each finger?

Part 1: Collecting Fingerprint Evidence from the Crime Scene (from hard surfaces)

At the crime scene, fingerprints must be removed and transported to the crime lab. They may then be compared to the database of fingerprints on file. One way that detectives locate fingerprints is by dusting for them. Fingerprints are coated with powder, then lifted and taken for identification at the lab.

1. Sprinkle cocoa powder over the object (for instance, a glass) and brush the powdered area gently with a fine brush (camel hair or fibreglass) to remove the excess powder and expose the print. On dark surfaces, use talcum powder instead of cocoa to lift the print.

2. Place a piece of transparent tape over the print and lift the print from the glass. Place the tape on light coloured construction paper.

Fingerprinting: Adapted from Mrs. Seagraves' QUEST Class and Thematic Units. Forensic Science Activities: <http://www.geocities.com/Athens/Atrium/5924/forensicscienceactivities.htm>. Copyright © 1999-2001 by S. Seagraves. Adapted by permission.

Alternative Method

1. Place the object (for example, cup) in a labelled zippered plastic evidence bag. Add about three drops of superglue to the bag, making sure that the drops do not hit the actual fingerprint.

2. In about an hour, the fingerprints should be clearly visible in white.

> **Caution:** Follow all directions when working with a strong adhesive, and pay particular attention to where fingertips are placed. Keep hands away from face and eyes.

Part 2: Making and Identifying Fingerprints

There are many methods of gathering fingerprints, but using a stamp pad to make fingerprints is a common method. Follow the procedure below to make fingerprint cards for possible suspects.

1. Make a fingerprint record chart, allowing space for the thumb, index, middle, ring, and baby fingerprints of each hand. Record the date, the individual's name, and the hand (left or right).

2. Roll the finger lightly on the stamp pad, and then roll the inked finger onto the space in the chart (you may have to practise this technique until you can produce a legible fingerprint).

3. Repeat this method for each finger on the right hand.

4. Examine each print and identify its pattern. Record this information on the chart.

5. Repeat Steps 1 to 4 for the left hand.

Part 3: Identifying an Unknown Fingerprint

1. Examine the fingerprint(s) obtained from the crime scene.

2. Compare fingerprint evidence to the fingerprints of the possible suspects.

Analysis

Record your analysis in your *Forensic Investigation Lab Book.*

1. Record your conclusions.

2. Explain clearly how you arrived at your conclusions.

3. Discuss as a class, or in a small group, the validity of using fingerprints collected from the scene of a crime to identify a suspect.

ESSENTIAL UNDERSTANDING 7: PHYSICAL EVIDENCE—FIBRE, STAIN, AND HAIR ANALYSIS

Teacher Background

In 1910, Edmund Locard founded a small police laboratory in Lyon, France, dedicated to forensic science. Locard put forward the theory that a criminal almost always leaves behind physical clues at the scene of a crime.

What looks like a bit of lint might actually offer numerous clues to an investigator. Scientists microscopically comb samples for human and animal hair, clothing threads, carpeting, paper, and even plant fibres. They may attempt to identify everything found at the crime scene, and perhaps use the information to place a suspect at the scene.

Forensic analysts are often asked to compare hair found at a crime scene with hair from a particular individual. Hair samples can be used to exclude a suspect but not to convict someone. Hair is considered to be contributing evidence. Different hairs on the same person can show variations, so a larger sample is better than a small one. The examiner compares a variety of factors, including colour, coarseness, granule distribution, hair diameter, and the presence or absence of a medulla. Hair may also carry evidence such as dirt or blood.

Each hair grows out of a tiny pocket in the skin called a follicle. The base of the hair (the part attached to the follicle) is called the root hair. The presence of the root hair may indicate that the hair was pulled out, as opposed to having fallen out. A strand of hair has three layers: cuticle, cortex, and medulla. The cuticle is the outer covering. It consists of tough overlapping scales that point toward the tip end. The cortex contains pigment granules, which give hair its colour. The colour, shape, and distribution of the granules provide important points of comparison between the hair of different individuals. The medulla is a hollow tube that runs the length of the hair. Sometimes it is present, sometimes not. Sometimes the canal is continuous, while in other cases it is fragmented. If the hair is from an animal, it may be possible to identify the species, since different species have different scale patterns on the cuticle of the hair. Animal hair characteristically has a thicker medulla and cuticle than human hair, thus providing more warmth.

Suggestions for Instruction

The following concepts may be developed in this section:

- ➤ physical properties of substance
- ➤ classification based on similarities and differences

- Brainstorm types of physical evidence that might be found at a crime scene.

Suggested Student Activities

- Activity 7a: Fibre and Stain Analysis
- Activity 7b: Hair Analysis

Activity 7a | Teacher Notes

Fibre and Stain Analysis

Specific Learning Outcomes

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.

SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

Students will observe, describe, compare, and classify various fibres (paper and cloth) and stains. They will then use this information to analyze evidence obtained at the crime scene.

Setting the Crime Scene

Give each group of forensic investigators one piece of the same kind of paper and one stained cloth (as described below).

Materials

Known samples may either be provided in labelled bags or the investigators must obtain them from the suspects. Six is an arbitrary number of samples.

- six samples of different paper (same colour, different types) in labelled bags
- six samples of different red cloth (all red, different types) in labelled bags
- four pieces of one type of cloth (each with a different stain and one left unstained) in labelled bags
- salt, vegetable oil, lead nitrate, and potassium iodide (to make the stain)
- hand lens
- compound microscope
- stereoscopic microscope
- tweezers
- slides and cover slips
- sticky tape (to gather evidence from the crime scene)

Procedure

Part 1: Examining Paper Fibres

Students examine six known types of paper (same colour, different types) and record observations using their eyes and then a hand lens, stereoscope, and/or microscope. Students examine texture, arrangement of fibres, and any other unique features. Students then examine the evidence obtained at the crime scene and compare it to the known samples.

Part 2: Examining Cloth Fibres

Students examine six known pieces of cloth (same colour, different types) and record observations using their eyes and then a hand lens, stereoscope, and/or microscope. Students examine texture, arrangement of fibres, and any other unique features. Students then examine the evidence obtained at the crime scene and compare it to the known samples.

Part 3: Identifying Unknown Stains

One important aspect of this part of the activity is to ensure that the stains are similar in appearance but different in composition. As well, the differences in the stains should be observed at the hand lens or microscopic level to ensure that students cannot differentiate between the stains at the normal eye level. The three stains that work well on red cloth consist of

- a mixture of salt and water (Once dry, the salt crystals will become trapped in the cloth.)
- a dilute solution of lead nitrate and potassium iodide solution (This yellow solution will dry to leave yellow lead iodide crystals.)
- a vegetable oil stain (On the red cloth, the stain will look like the two other stains, but will be caused by discolouration in the material rather than by crystals.)

Students examine the four known cloth samples (three stained and one unstained). They then observe the unknown sample from the crime scene and match it to one of the three known stains. Using another type of material for one stain sample would force students to concentrate more on the stains than on the material.

Activity 7a

Student Page

Fibre and Stain Analysis

Background

In 1910, Edmund Locard founded a small police laboratory in Lyon, France, dedicated to forensic science. Locard put forward the theory that a criminal almost always leaves behind physical clues at the scene of a crime.

What looks like a bit of lint might actually offer numerous clues to an investigator. Scientists microscopically comb samples for human and animal hair, clothing threads, carpeting, paper, and even plant fibres. They may attempt to identify everything found at the crime scene, and perhaps use the information to place a suspect at the scene.

Objectives

- Observe and record the characteristics of various samples of paper fibres, cloth fibres, and stains on cloth.
- Use similarities and differences of collected samples as a means of identification.
- Attempt to match the physical evidence obtained from the crime scene to a suspect.

Materials

- paper samples
- cloth samples
- hand lens
- compound microscope
- stereoscopic microscope
- tweezers
- slides and cover slips
- sticky tape

Procedure

Construct an organized data table to record your results and observations in your *Forensic Investigation Lab Book*. Be sure to include detailed and labelled diagrams and note the magnification.

Part 1: Examining Paper Fibres

1. Examine each of the known paper samples with your eyes, the hand lens, stereoscope, and/or compound microscope. Note colour, texture, arrangement of fibres, and any other observable features. Record your observations.
2. Examine the paper sample obtained at the crime scene. Record your observations.

Part 2: Examining Cloth Fibres

1. Examine each of the known cloth samples with your eyes, the hand lens, stereoscope, and/or compound microscope. Note colour, texture, arrangement of fibres, and any other observable features. Record your observations.
2. Examine the cloth sample obtained at the crime scene. Record your observations.

Part 3: Identifying Unknown Stains

1. Obtain four different pieces of cloth (one unstained, and three stained—each with a different stain). Each piece should be numbered.
2. Observe each stain with your eyes, the hand lens, stereoscope, and/or compound microscope. Record your observations of the stain.
3. Examine the sample of the unknown stain from the crime scene and record your observations.

Analysis

Record your analysis in your *Forensic Investigation Lab Book*.

1. Determine which of the known paper and cloth samples most closely matches the unknown and record the number and type. Justify your choice each time.

2. Does the examination of fibre evidence provide valid scientific data and allow forensic investigators to link crime scenes to individuals? Explain.

3. Outline a recent case in Canada where hair and/or fibre evidence was called into question as a primary means of obtaining a conviction. In the case you uncovered, was the person set free due to problems with this sort of evidence? Explain.

Activity 7b **Teacher Notes**

Hair Analysis

Specific Learning Outcomes

SLO A2:	Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
SLO B2:	Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.
SLO C1:	Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

Students will observe, describe, compare, and classify various types of hair samples based on their characteristics. Students then examine the evidence obtained at the crime scene and compare it to the known samples.

Setting the Crime Scene

Leave hair samples for each group at the crime scene. You may choose to leave more than one type (for instance, some from the suspect, a dog or cat, or a victim). Students may use sticky tape to gather evidence from the crime scene.

Materials

- hair (your own or from friends, family members, hair salon, family pet, or other animal) in labelled bags
- hand lens
- compound microscope
- stereoscopic microscope
- tweezers
- slides and cover slips
- sticky tape

Procedure

Have students draw and describe at least six different types of hair using their eyes, the hand lens, stereoscope, and microscope. Students may note the presence or absence of a hair follicle, hair colour, coarseness, granule distribution, hair diameter, and the presence or absence of a medulla.

Activity 7b

Student Page

Hair Analysis

Background

Forensic analysts are often asked to compare hair found at a crime scene with hair from a particular individual. Different hairs on the same person can show variations, so the larger the sample the better. The examiner compares a variety of factors, including colour, coarseness, granule distribution, hair diameter, and the presence or absence of a medulla. Hair may also carry evidence such as dirt or blood.

Each hair grows out of a tiny pocket in the skin called a follicle. The base of the hair (the part attached to the follicle) is called the root hair. The presence of the root hair may indicate that the hair was pulled out, as opposed to having fallen out. A strand of hair has three layers: cuticle, cortex, and medulla. The cuticle is the outer covering. It consists of tough overlapping scales that point toward the tip end. The cortex contains pigment granules, which give hair its colour. The medulla is a hollow tube that runs the length of the hair. Sometimes it is present, sometimes not. Sometimes the canal is continuous, while in other cases it is fragmented. If the hair is from an animal, it may be possible to identify the species, since different species have different scale patterns on the cuticle of the hair. Animal hair characteristically has a thicker medulla and cuticle than human hair, thus providing more warmth.

Objectives

- Observe and record the characteristics of various samples of hair.
- Use similarities and differences in collected samples as a means of identification.
- Attempt to match the physical evidence obtained from the crime scene to a suspect.

Materials

- hair samples
- hand lens
- compound microscope
- stereoscopic microscope
- tweezers
- slides and cover slips
- sticky tape

Procedure

Construct an organized data table to record your observations and results in your *Forensic Investigation Lab Book*. Be sure to include detailed and labelled diagrams and note the magnification.

1. Obtain six known samples of hair.
2. Examine the hair with your eyes, the hand lens, stereoscope, and microscope. Record your observations. Note characteristics such as colour, thickness, texture, and any unique characteristics such as split ends. Remember to observe both ends of the hair.
3. Make a wet mount slide of a hair.
4. Observe the hair with the compound microscope and record its characteristics, including colour, thickness, texture, and any unique characteristics such as split ends. Remember to observe both ends of the hair. Look for medulla, cuticle, and scales. Look for the distribution of pigment granules.
5. Record and make drawings of your observations.
6. Repeat this procedure for the other hair samples. Note and record any differences.
7. Examine the hair sample(s) obtained from the crime scene.
8. Examine and record your observations.

Analysis

Record your analysis in your *Forensic Investigation Lab Book*.

1. Determine whether the hairs at the crime scene are from the victim or from one of the suspects.

2. Justify your decision.

3. Does the examination of hair fibre evidence provide valid scientific data and allow forensic investigators to link crime scenes to individuals? Explain.

4. Outline a recent case in Canada where hair and/or fibre evidence was called into question as the primary means of obtaining a conviction. In the case you uncovered, was the person set free due to problems with this sort of evidence? Explain.

ESSENTIAL UNDERSTANDING 8: HANDWRITING ANALYSIS

Specific Learning Outcomes

SLO A1:	Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.
SLO A2:	Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
SLO A3:	Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.
SLO C1:	Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Teacher Background

Handwriting analysis involves the study of shapes, forms, and inconsistencies. Just as in fingerprinting analysis, forensic scientists will examine a combination of characteristics when attempting to identify a particular handwriting. They will examine the way the lines form the letters, the slant (forward, backward, or straight up and down), spacing, and ornamentation (dotting of i's, crossing of t's). Forensic investigators also use psycholinguistic analysis to examine a person's choice of words, spelling, punctuation, and grammar in written (and spoken) communication.

When making handwriting comparisons, the forensic scientist will attempt to obtain an exemplar or sample of the person's handwriting. The scientist may have the individual re-create the document, using the same writing tools and paper and taking dictation at varying speeds and emphases. The scientist may also obtain writing samples by searching through an individual's effects.

Handwriting analysts maintain that lying results in slight physiological changes that might affect the slant, pressure, or spacing in writing. Those who try to disguise their style of writing often write faster than normal, are deliberately careless, or write smaller or larger than they normally do. They may also try to change the slant of their writing. They may print instead of write, or they may change hands. If forensic scientists have enough handwriting samples from the suspect, they can usually determine whether or not the suspect has written certain documents.

Being somewhat subjective, handwriting analysis is not a science, and handwriting analysts are often not accepted as expert witnesses in trials.

Suggestions for Instruction

> The following concept could be developed in this section:
> ➤ classification based on similarities and differences

- Use an activating prior knowledge activity (see Appendix 2) to establish what students know about handwriting.
- Have students make and classify a number of handwriting samples within the classroom. They may then practise trying to identify each other based on their handwriting. Consider varying the conditions under which the samples are created (for example, time, distractions) and/or have students try to fool each other.

Suggested Student Activities

- Activity 8: The Science of Handwriting Analysis?
- Students research, discuss, and debate whether handwriting analysis is a science in the strict sense (see *SYSTH* 4.19–4.21).
- Students could research the ransom notes sent after the kidnapping of Charles A. Lindbergh, Jr. (1932), the young son of the famous aviator, or they could research Clifford Irving's forgery of letters and the autobiography he claimed Howard Hughes had written (1970).

Activity 8 **Teacher Notes**

The Science of Handwriting Analysis?

Specific Learning Outcomes

SLO A1:	Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.
SLO A2:	Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.
SLO A3:	Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.
SLO C1:	Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Background

The individuality of each person's handwriting comes from the individuality of each person's motor control pattern. It is because each body's motor control pattern is unique that handwriting can be used for identification.

Setting the Crime Scene

Leave a note (see also Activity 3: Chromatography and Activity 7a: Fibre and Stain Analysis) at the crime scene. The note may give clues to the crime. Have someone "forge" the handwriting and/or signature of the writer of the note (victim or suspect). What the note contains and where the evidence points will be developed in your initial crime scenario.

Materials

- sheet of signatures
- unlined white paper
- tracing paper
- pen
- rulers

Procedure

Part 1: Introduction to Handwriting Analysis

Discuss with students the possible uses of handwriting analysis. Ask them whether they think handwriting analysis is a science. Have students examine their own signatures in a variety of ways.

Part 2: Identifying Authentic Signatures (Practice)

Write your signature at the top of a sheet of paper. Have five or six other persons closely imitate your signature below it. Include at least one other legitimate signature in the mix. Distribute copies of the sheet to the forensic investigative teams to see whether they can determine which signatures are forged and which are legitimate.

Part 3: Examining the Handwriting/Signature on a Note Found at the Crime Scene

The forensic investigative teams will examine the signature(s) found on the note(s) at the crime scene and compare the signature(s) to those of the victim(s) and/or suspect(s).

Activity 8 **Student Page**

The Science of Handwriting Analysis?

Background

The individuality of each person's handwriting comes from the individuality of each person's motor control pattern. It is because each body's motor control pattern is unique that handwriting can be used for identification.

When examining each suspect's handwriting, look at the following:

- slant
- size of letters
- distinct formations
- spacing of letters
- spacing of words

Objective

- Create and examine signatures/handwriting samples to establish personality traits that could assist in suspect identification.

Materials

- sheet of signatures (provided by teacher)
- unlined white paper
- tracing paper
- pen
- ruler

Procedure

Record your observations and results in your *Forensic Investigation Lab Book*.

Part 1: Introduction to Handwriting Analysis

1. On an unlined sheet of paper, write your signature three times: first normally, then holding your pen in a fist moving only the wrist and arm, and finally with the pen clenched in the crook of your elbow. What do you notice about your signatures?
2. Write your name in the air with your nose or foot. What do you notice?
3. Write your name twice on a sheet of white paper and place tracing paper over the signatures. Make a small mark on the tracing paper at the high point of each letter of both signatures. Use a ruler to connect the consecutive dots, creating a zigzag line across the top of each signature. What do you notice about the two zigzag lines?

Part 2: Identifying Authentic Signatures (Practice)

1. With your forensic investigative team, examine the sheet of signatures distributed by the teacher.
2. The topmost signature is that of your teacher. One or two other signatures below are also legitimate signatures. Attempt to determine which signatures are forged and which are legitimate.
3. Record your results. Explain your reasoning.

Part 3: Examining the Handwriting/Signature on a Note Found at the Crime Scene

1. Construct an organized data table to examine the slant, size of letters, distinct formations, spacing of letters, and spacing of words in each suspect's handwriting.
2. Obtain the written evidence gathered at the crime scene.
3. Examine the handwriting and signature(s) in detail.
4. Examine the exemplars of handwriting obtained for the victim(s) and/or suspect(s). Compare the exemplars with the crime scene evidence.

Analysis

Record your analysis in your *Forensic Investigation Lab Book*.

1. Who do you think wrote the note? Why? Record your conclusions.

2. Is handwriting analysis a useful skill for forensic investigators? Explain.

ESSENTIAL UNDERSTANDING 9: CHEMICAL DETECTION

Teacher Background

A forensic scientist may discover powder or other unknown substances at a crime scene. To identify the unknown substance, a forensic chemist will perform a variety of chemical tests.

Suggestions for Instruction

The following concepts could be developed in this section:

- ➤ characteristic properties of substances (Senior 3 Chemistry)
- ➤ chemical reactions (Senior 3 Chemistry)

- Use a Compare and Contrast strategy (see *SYSTH* 10.15-10.17) to review physical and chemical characteristics.

Suggested Student Activities

- Activity 9: Chemical Detection
- Students conduct research on arson dogs trained to detect chemical compounds used to set fires that can indicate foul play.

Activity 9 | Teacher Notes

Chemical Detection

Specific Learning Outcomes

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

Students perform a variety of positive tests on known white powders. They will learn how to determine the composition of a mystery powder through observation and classification of reaction type.

Setting the Crime Scene

Leave a small sample of one of the following powders (or a mixture of powders) at the crime scene: salt, sugar, cornstarch, baking soda, plaster, and potassium iodide. Leave enough for each group to scrape up a sample. If possible, try to connect the powder to the suspects (guilty or innocent) or the victim. The sample could also be a red herring.

Materials

- salt
- sugar
- cornstarch
- baking soda
- plaster
- potassium iodide (KI)
- vinegar
- iodine (from KI solution)
- water
- lead II nitrate solution $Pb(NO_3)_{2(aq)}$
- black paper
- hand lens or microscope
- clothespin
- aluminum
- hotplate or candle
- spot/well plate or egg carton
- eyedropper
- toothpicks

Procedure

Part 1: Determining the Characteristics of Various White Powders

Students perform a series of tests on six unknown powders. By determining what a positive test for the powder is, they will be able to determine the composition of an unknown powder that may contain more than one type of white powder. The following table shows the positive test for each of the powders. NR means no recordable reaction.

Test Results

Test / Powder	Appearance (Hand Lens/ Microscope)	Heat Test	Vinegar Test	Iodine Test	Solubility in Water Test	Reaction with Lead II Nitrate Test
Salt	White crystals	NR	NR	NR	Dissolves	NR
Sugar	White crystals	Turns brown	NR	NR	Dissolves	NR
Cornstarch	Fine-grained powder	NR	NR	Black	Clumps	NR
Baking Soda	Fine-grained powder	NR	Bubbles	NR	Minor dissolving	NR
Plaster	Powder	NR	NR	NR	Does not dissolve	NR
Potassium Iodide	Clear crystals	NR	NR	NR	Dissolves	Yellow

Part 2: Identifying an Unknown Mixture of White Powders

Make up sample mystery powders using two or more of the white powders. Have students identify the mystery powders using the same tests. Use codes for each sample, recording the composition of the mystery powders for each code. The emphasis in this task is on having students perform the tests correctly and record the data in an appropriate manner that allows them to draw conclusions that can be supported by their data.

Part 3: Identifying the Unknown Powder from the Crime Scene

Students analyze the powder evidence gathered from the crime scene using the tests previously practised in this investigation.

Activity 9 Student Page

Chemical Detection

Background

Crime labs work with pharmaceutical companies to develop tests for drugs as they are developed. Forensic investigators are able to identify very small samples of a drug, using files developed through previous positive testing as a reference. Drug identification is very important, especially when investigators arrive on a scene to find someone has ingested a potentially poisonous drug.

Objectives

- Perform several tests on small amounts of known white powders to determine which produces a positive reaction.
- Identify the different powders in a mystery mixture that contains at least two known powders.
- Analyze and identify powder evidence left at the crime scene.

Materials

- salt
- sugar
- cornstarch
- baking soda
- plaster
- potassium iodide (KI)
- vinegar
- iodine (from KI solution)
- water
- lead II nitrate solution $Pb(NO_3)_{2(aq)}$
- black paper
- hand lens or microscope
- clothespin
- aluminum
- hotplate or candle
- spot/well plate or egg carton
- eyedropper
- toothpicks

Procedure

You are going to test six different powders. Construct a well-organized data table in your *Forensic Investigation Lab Book*, in which you will record all your observations. You will then have a set of positive tests, ways to tell each powder from the others. You will then practise on an unknown powder. Finally, you will analyze the powder collected at the crime scene.

Part 1: Determining the Characteristics of Various White Powders

Test #1: Hand Lens/Microscope Test

1. Place a small amount of each powder on a square of black paper and observe the particles with a hand lens. Examine the appearance of each powder. Describe shape, grain size, and other notable characteristics.
2. Rub each powder between your fingers and describe its texture.
3. Use the wafting technique to note any odours to the powders.
4. Record your observations in the data table.
5. Dispose of the powders as directed by the teacher.

Test #2: Heat Test

1. Make a foil boat or a foil spoon (use a clothespin for a handle).
2. Place a small amount of each powder in the foil.
3. Hold the spoon over a candle flame or place the boat on a hotplate.
4. Heat the powder carefully.
5. Record your observations in the data table.

Test #3: Vinegar Test

1. Place a small amount of each powder in a separate well on a spot plate (or egg carton).
2. Add a few drops of vinegar to each powder. Stir with a clean toothpick each time.
3. Record your observations in the data table.
4. Clean the spot plate.

Test #4: Iodine Test

Caution: Handle iodine with care. Do not touch with bare hands!

1. Place a small amount of each powder in a separate well on a spot plate (or egg carton).
2. Add a few drops of iodine (KI solution) to each powder. Stir with a clean toothpick each time.

3. Record your observations in the data table.
4. Clean the spot plate.

Test #5: Solubility in Water Test

1. Place a small amount of each powder in a separate well on a spot plate (or egg carton).
2. Add a few drops of water to each powder. Stir with a clean toothpick each time.
3. Record your observations in the data table.
4. Clean the spot plate.

Test #6: Reaction with Lead II Nitrate Test

1. Place a small amount of each powder in a separate well on a spot plate (or egg carton).
2. Add a few drops of lead II nitrate solution to each powder. Stir with a clean toothpick each time.
3. Record your observations in the data table.
4. Clean the spot plate.

Part 2: Identifying an Unknown Mixture of White Powders

1. Take one unknown mixture from the tray and record the number of the mixture. Each mixture contains two or three of the known powders in different combinations.
2. Identify which powders are present in the unknown mixture, using the positive tests determined in Part 1.
3. Construct a table to summarize your observations and conclusions.

Part 3: Identifying the Unknown Powder from the Crime Scene

Analyze the powder evidence gathered from the crime scene using the tests you have practised in this investigation. Record your observations in your *Forensic Investigation Lab Book.*

Analysis

Record your analysis in your *Forensic Investigation Lab Book*.

1. Describe a positive test for each of the unknown white powders.

2. Explain how you determined the composition of your unknown mixture.

3. Give an example of how the procedures you used today could be used to collect and analyze evidence at a crime scene.

ESSENTIAL UNDERSTANDING 10: SOIL ANALYSIS

Teacher Background

Soil may be defined as the naturally deposited material covering the earth's surface whose chemical, physical, and biological properties are capable of supporting plant growth. Soils vary widely in their composition, depending on their origin and the natural forces of erosion and decomposition acting upon them over time.

The analysis of soil from a crime scene often provides investigators with clues. For example, properties of a certain type of soil, such as the acidity or alkalinity (pH) or the capillary action, can place the suspect in a certain geographical place. As bodies decompose, they leak fatty acids into the ground beneath them. Analysis of the types and amounts of fatty acids can reveal the time of death, as well as pinpoint exactly how long any given body has been lying in a particular place. The soil, saturated with bone minerals and fatty acids, can also reveal the presence of a corpse, even if the body itself has been removed or destroyed. The "stain" left by a body's *volatile acids* ("volatile" meaning very easily taken up into the air as vapour), which also suppress plant life around it, can last up to two years, leaving a kind of phantom "fingerprint" in the earth. Thus, soil, like maggots, offers much forensic information.

Suggestions for Instruction

> The following concept could be developed in this section:
> - ➤ soil types and formation

- Discuss the factors involved in soil formation, such as living matter (plants, animals, and micro-organisms), climate (cold, heat, snow, rainfall, and wind), parent materials (chemical and mineralogical composition), relief (slope and land form), and time.
- Discuss the different soil types (loam, sandy loam, clay loam, and humus loam).

Suggested Student Activity

- Activity 10: The Dirty Truth

Activity 10 **Teacher Notes**

The Dirty Truth

Specific Learning Outcomes

SLO A5:	Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.
SLO B5:	Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.
SLO D1:	Use the concepts of similarity and diversity for organizing our experiences with the world.

Overview

Students will make a shoe print mould, examine soil microscopically, assess the capillary action of soil, determine the water-holding capacity of soil, and determine the soil's pH. One way to obtain a variety of soil samples is by having students bring them from home.

Setting the Crime Scene

Leave a shoe (or tire) print in soil at the crime scene. Have a number of different (labelled) shoes (with different soil samples stuck to them) available for comparison.

Materials

- plaster of Paris powder
- known soil samples with specific percentages of sand, clay, and humus (You may premix these yourself.)
- unknown soil sample evidence from crime scene
- sand
- clay
- humus
- powder funnel
- cloth gauze
- elastic band
- stereoscopic microscope
- 100 ml graduated cylinder
- 250 ml beaker
- pH paper
- water
- clock or watch

Procedure

Part 1: Making a Mould of Shoe (or Tire) Print

The investigative teams use plaster of Paris to make a mould of the shoe (or tire) print left at the crime scene.

Part 2: Examining Soil Microscopically

Students examine known and unknown soil samples microscopically.

Part 3: Assessing the Capillary Action of Soil

Students determine the capillary action of known and unknown soil samples.

Part 4: Determining the Water-Holding Capacity of Soil

Students determine the water-holding capacity of known and unknown soil samples.

Part 5: Determining the pH of Soil

Students determine the pH of known and unknown soil samples.

Activity 10 Student Page

The Dirty Truth

Background

Soil may be defined as the naturally deposited material covering the earth's surface whose chemical, physical, and biological properties are capable of supporting plant growth. Soils vary widely in their composition, depending on their origin and the natural forces of erosion and decomposition acting upon them over time.

The analysis of soil from a crime scene often provides investigators with clues. For example, properties of a certain type of soil, such as the acidity or alkalinity (pH) or the capillary action, can place the suspect in a certain geographical place. As bodies decompose, they leak fatty acids into the ground beneath them. Analysis of the types and amounts of fatty acids can reveal the time of death, as well as pinpoint exactly how long any given body has been lying in a particular place. The soil, saturated with bone minerals and fatty acids, can also reveal the presence of a corpse, even if the body itself has been removed or destroyed. The "stain" left by a body's *volatile acids* ("volatile" meaning very easily taken up into the air as vapour), which also suppress the growth of plant life around it, can last up to two years, leaving a kind of phantom "fingerprint" in the earth. Thus, soil, like maggots, offers much forensic information.

Objectives

- Classify soils based on their physical and chemical characteristics.
- Classify unknown soil from the crime scene.

Materials

- plaster of Paris powder
- known soil samples with specific percentages of sand, clay, and humus
- unknown soil sample evidence from crime scene
- sand
- clay
- humus
- powder funnel
- cloth gauze
- elastic band
- stereoscopic microscope
- 100 ml graduated cylinder
- 250 ml beaker
- pH paper
- water
- clock or watch

Procedure

Record your observations, drawings, data, and conclusions in your *Forensic Investigation Lab Book*.

Part 1: Making a Mould of Shoe (or Tire) Print

1. Mix the plaster of Paris as directed.
2. Pour a thin layer of the plaster into the shoe (or tire) impression left at the crime scene. Make sure that the entire impression is covered and try to avoid bubbles. Let the plaster dry.
3. Once the mould has hardened, carefully remove the mould from the imprint.
4. Measure the length and width of the mould.
5. Examine and draw the tread.
6. Compare your mould and data to the available shoe samples and record your conclusions.

Part 2: Examining Soil Microscopically

1. Obtain small samples of sand, clay, and humus.
2. Using a stereoscopic microscope, make drawings of each sample.
3. Examine and draw your unknown sample. Try to identify the sand, clay, and humus in your sample.
4. Classify the unknown sample as loam, sandy loam, or clay loam. Record your conclusions.

Part 3: Assessing the Capillary Action of Soil

1. Wet a square piece of gauze and attach it to the bottom of a powder funnel using an elastic band.
2. Measure 100 ml of water into a 250 ml beaker.
3. Weigh out 100 g of one of the known soil samples.
4. Place the soil sample in the funnel and pack it down firmly.
5. Place the funnel in the beaker. Make sure the stem of the funnel reaches the water. Depending upon the relative amounts of sand, clay, and humus in the soil sample, water will be absorbed up from the beaker into the soil.
6. Measure the amount of water remaining in the beaker after every five minutes for 30 to 60 minutes.
7. Record the absorption data.
8. Retain the soil sample and funnel for Part 4.
9. Using a new funnel, repeat the procedure with your unknown soil sample.
10. Graph the rate of water uptake versus time for both soil samples. Find the slopes of each graph and describe the significance of each slope.

Part 4: Determining the Water-Holding Capacity of Soil

1. After Part 2 is completed, place the powder funnel containing the soil sample from Part 2 over the empty 100 ml graduated cylinder.
2. Pour the remainder of the 100 ml of water from the 250 ml beaker into the soil sample.
3. Allow the water to run through the packed soil sample.
4. When the water has stopped running through, record the amount of water that ran through the soil sample into the graduated cylinder.
5. Record the volume of water held (volume held = 100 ml – volume in graduated cylinder).
6. Keep the water in the graduated cylinder for Part 5.
7. Repeat Part 4 procedure using your unknown soil sample.

Part 5: Determining the pH of Soil

1. Use the water sample that passed through the soil sample in Part 4 and the pH paper to determine the pH of the known and unknown soil samples.
2. If the water is coloured or clouded by soil particles, filter or centrifuge it to obtain a sample that is as clear as possible.

Analysis

1. Summarize your conclusions based on the evidence obtained from the soil samples.

ESSENTIAL UNDERSTANDING 11: URINE ANALYSIS

Teacher Background

Urine analysis is a crucial and interesting exploration for students. With the necessary cautions in place regarding the use of natural body fluids, it is essential that students handle only *synthetic urine* that has been produced artificially. One good "recipe" for synthetic urine follows later on in this activity. From a forensic investigation point of view, urine analysis can reveal characteristics of an individual's body chemistry *at a moment in time*, making such an analysis useful for time and date related to crime scene investigations.

Among the characteristics that can be examined for a urine sample, the following are important for the purposes of this urine analysis activity:

- **Visual examination:** Colour, transparency, turbidity, and odour(s) are considered important attributes in this initial examination.
- **Specific gravity:** Synonymous with *density*, specific gravity (as measured by a hydrometer) provides a comparison with pure water ($s.g._{water} = 1.00$), and also gives evidence of the amount of dissolved solids in the urine sample, the degree to which the sample is dilute, or the presence of health problems. A high specific gravity is indicative of greater dissolved solids and can indicate dehydration.
- **pH:** Urine pH can vary from about 4.5 (quite acidic) to 8.0 (slightly alkaline), and is an indicator of diet, drug use, and other factors. It also has the advantage of being a time-specific data source that can have value in a forensic investigation.
- **Sediment analysis:** Analysis of sediment can provide clues such as an abnormal condition of blood in urine or the presence of crystals that may indicate drug use. Students could be provided with diagrams to assist in identification, particularly in the case of the identification of crystals that have precipitated out of the urine suspension.
- **Protein presence (e.g., albumin):** Normally, protein should not be present in urine, and is an indicator of problems if it is present. For instance, fever, strenuous exercise, and some diseases (especially kidney disease) may cause protein to appear in urine. The presence of protein in urine may also be an indication of normal pregnancy.
- **Glucose presence:** Testing for sugar (as glucose) may give an indication of diseases such as diabetes or kidney dysfunction. Under normal conditions, sugar(s) should not be present in urine.

Suggestions for Instruction

The following concepts may be developed in this section:
- ➤ kidney function and disease (Senior 3 Biology)
- ➤ chemical reactions (Senior 3 Chemistry)

- Review/discuss kidney function and urine formation. Include a look at conditions and diseases that might be tested for with a urine test.

Suggested Student Activity

- Activity 11: Urine Analysis

Activity 11 **Teacher Notes**

Urine Analysis

Specific Learning Outcomes

SLO B3:	Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.
SLO C4:	Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.
SLO D2:	Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

Overview

Students will perform different tests on *synthetic urine*. Each test will provide possible clues for the investigator. Many of the results will provide clues rather than a direct result. Students will have to evaluate the relevance of the data in the context of the situation.

Setting the Crime Scene

You might choose to leave a urine sample (of suspect/victim) at the crime scene and/or have the investigative teams gather urine samples from the various suspects. The sample might give clues to the investigation, might match to a suspect, or might be a red herring.

Materials

- stock and sample urine solutions (preparation instructions follow)
- hydrometers
- pH testing paper
- centrifuge
- microscope (including slides and cover slips)
- test tubes
- beakers
- hot plate
- Benedict’s solution
- water
- clock or watch

Preparation of Urine Samples

For Tests 1 to 6 of this Urine Analysis activity, make the following solutions.

<table>
<tr><th>Basic Stock Solution</th><th>Basic Stock Solution with Additives</th><th>Basic Stock Solution with Additives and Impurities: Sample Solutions for Crime Scene</th></tr>
<tr><td>To 1 L of distilled water, add:
• 3 g sodium chloride (NaCl)
• 3 g ammonium oxalate
• 3 g potassium phosphate</td><td>To the 1 L Basic Stock Solution, add:
• 2 drops of 1M HCl
• 1 acetylsalicylic acid (ASA) tablet
• 1 g glucose
• 1 g albumin powder
• 5 g urea
• blood cells (obtain fresh meat from butcher or meat department)</td><td rowspan="2">To a 1 L Basic Stock Solution with Additives, add:
Sample 1:
• 24 ml 0.1M $NH_{3(aq)}$
• 1 g glucose
Sample 2:
• 5 g urea
• 1 g albumin powder
Sample 3:
• 1 g glucose
• 1 g albumin powder
• blood cells (from fresh meat)
Sample 4:
• 1 ASA tablet
• 2 drops of 3M HCl</td></tr>
<tr><td colspan="2">Note:
• Solutions will keep for about a week in the fridge.
• Adjust pH as required.
• Fresh blood cells should be added to appropriate sample(s) each time the sample is used as they tend to lyse in solution.
• Blood obtained from butcher or meat department usually contains few whole blood cells. Centrifuge blood and pour off liquid. Re-suspend cells in a small portion of “urine” and add to sample.</td></tr>
</table>

Sample Preparation Key

Sample	pH	Protein (Albumin)	Glucose	Sediment			Specific Gravity
				Amorphous Phosphate	Crystals	Blood Cells	
1	8	–	+	+	Oxalate	–	Varies
2	6	+	–	+	Oxalate	–	Varies
3	6	+	+	+	Oxalate	+	Varies
4	2/3	–	+	+	Oxalate, Acetylsalicylic Acid	–	Varies

Procedure

Part 1: Analyzing Known Urine Samples

Test 1: Making Initial Examination of Urine

Students make a visual examination of the odour and colour of the *synthetic urine* sample. Even though the urine is synthetic, it may take some time for students to settle down with the idea of working with urine. It is important for them to consider the samples real and to perform the procedures accordingly. This means that they should keep their equipment clean and be aware of potential health concerns if they spill their samples.

Test 2: Determining Specific Gravity of Urine

Some time may be needed to show the class the proper use of a hydrometer to determine specific gravity. Students should understand that having a change in the specific gravity of urine could indicate a medical problem.

Test 3: Testing for pH of Urine

Students use pH testing paper to determine the pH of urine.

Test 4: Analyzing Sediment

Analysis of sediment can provide clues such as an abnormal condition of blood in the urine or the presence of crystals that may indicate drug use. Students could be provided with diagrams to assist in identification, or this step can be omitted.

Test 5: Testing for Presence of Albumin (a Protein)

Students heat part of the liquid (supernatant) fraction of the urine. If protein is present, it will denature and make the solution cloudy.

Test 6: Testing for Presence of Glucose

Testing for sugar may give an indication of diseases, such as diabetes. Students will need to use care when working with Benedict's solution and a hot plate.

Part 2: Analyzing Unknown Urine Sample (Practice)

Given a choice of samples to choose from, students are to determine the composition of the urine by performing the tests. Each sample has a different set of conditions. You may choose to make up your own samples or follow the sample preparation key provided.

Part 3: Analyzing Evidence from the Crime Scene

Students use the procedures they have practised to analyze the unknown sample(s) from the crime scene/suspects.

Activity 11 Student Page

Urine Analysis

Background

Urine analysis is a crucial and interesting exploration. With the necessary cautions in place regarding the use of natural body fluids, it is essential that you handle only *synthetic urine* that has been produced artificially. From a forensic investigation point of view, urine analysis can reveal characteristics of an individual's body chemistry *at a moment in time*, making such an analysis useful for time and date related to crime scene investigations.

Among the characteristics that can be examined for a urine sample, the following are important for the purposes of this urine analysis activity:

- **Visual examination:** Colour, transparency, turbidity, and odour(s) are considered important attributes in this initial examination.
- **Specific gravity:** Synonymous with *density*, specific gravity (as measured by a hydrometer) provides a comparison with pure water ($s.g._{water} = 1.00$), and also gives evidence of the amount of dissolved solids in the urine sample, the degree to which the sample is dilute, or the presence of health problems. A high specific gravity is indicative of greater dissolved solids and can indicate dehydration.
- **pH:** Urine pH can vary from about 4.5 (quite acidic) to 8.0 (slightly alkaline), and is an indicator of diet, drug use, and other factors. It also has the advantage of being a time-specific data source that can have value in a forensic investigation.
- **Sediment analysis:** Analysis of sediment can provide clues such as an abnormal condition of blood in urine or the presence of crystals that may indicate drug use.
- **Protein presence (e.g., albumin):** Normally, protein should not be present in urine, and is an indicator of problems if it is present. For instance, fever, strenuous exercise, and some diseases (especially kidney disease) may cause protein to appear in urine. The presence of protein in urine may also be an indication of normal pregnancy.
- **Glucose presence:** Testing for sugar (as glucose) may give an indication of diseases such as diabetes or kidney dysfunction. Under normal conditions, sugar(s) should not be present in urine.

Objectives

- Conduct various tests on a known urine sample to identify characteristics of urine.
- Identify the characteristics of an unknown urine sample.
- Examine the unknown sample obtained as evidence from the crime scene.

Materials

- stock and sample urine solutions (provided by teacher)
- hydrometers
- pH testing paper
- centrifuge
- microscope (including slides and cover slips)
- test tubes
- beakers
- hot plate
- Benedict's solution
- water
- clock or watch

Procedure

In your *Forensic Investigation Lab Book*, design a table for recording your results. The table should have space to record your data and drawings for various tests on two known samples, one unknown practice sample, and the evidence from the crime scene.

Part 1: Analyzing Known Urine Samples

Test 1: Making Initial Examination of Urine

1. Examine each urine sample for odour. Describe the odour you smell.
2. Comment on the colour of each sample. Use terminology such as yellow, amber, dark, pale, and so on.
3. Describe the clarity of each sample. Use terminology such as clear, cloudy, and so on.

Test 2: Determining Specific Gravity of Urine

1. Remove the hydrometer from its cylinder and empty the water from the cylinder into the sink. Fill the hydrometer cylinder three quarters full with the urine sample.
2. With a spinning motion, float the hydrometer in the urine. Make sure that the hydrometer stays suspended in the urine and does not adhere to the sides of the cylinder.
3. When the hydrometer has stopped spinning and is not touching the sides of the cylinder, read the specific gravity of each sample at the bottom of the meniscus formed at the hydrometer column. Record the specific gravity.
4. Pour the urine sample in the hydrometer cylinder into a test tube for Tests 3 and 4 of the activity. Pour any remaining urine back into the sample container.
5. Rinse and repeat with each sample.
6. Rinse and fill the hydrometer cylinder with water and place the hydrometer in the water.

Test 3: Testing for pH of Urine

1. Use pH testing paper to test the sample.

2. Compare with the coloured pH scale provided.

3. Record the pH in the table.

4. Repeat with each sample.

Test 4: Analyzing Sediment

1. In this test, you will be looking for blood cells, crystals, and phosphate granules in the urine sample. The presence of blood cells in the urine may be indicative of an abnormal condition, and the crystals may indicate the presence of drugs.

2. Fill one small test tube with the urine sample.

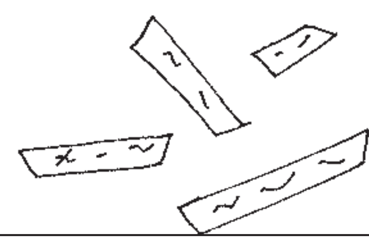
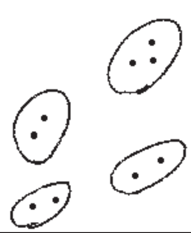
3. Set the tube in the centrifuge opposite someone else's sample and spin it for five minutes. (Please check with the teacher to make sure that your setup is correct before you turn on the centrifuge).

4. After centrifuging, pour off the liquid or supernatant and place it into a clean test tube. Place the test tube to the side to be used in Test 5.

5. Shake the test tube to re-suspend the sediment in the small amount of urine left in the test tube. Pour this onto a slide and prepare a wet mount to observe under the microscope.

6. Describe the sediment you observe under the microscope. (Remember to note any blood cells, phosphate granules, or crystals you observe.)

7. Repeat with each sample.

What You May See in the Urine Sample	
	
Amorphous phosphates (normal)	Oxalate crystals (normal)
	
Red blood cells (may indicate disease)	Acetylsalicylic acid crystals (Aspirin present)

Test 5: Testing for Presence of Albumin (a Protein)

1. Observe and record the clarity of the supernatant.
2. Separate the supernatant into two parts. Place one part to the side for use in Test 6.
3. Place the second part of the supernatant in a test tube. Then place the test tube in a hot water bath.
4. Compare the cloudiness of the heated supernatant with the unheated portion of the supernatant. If cloudiness increases in the heated sample, then protein is present.
5. Repeat with each sample.

Test 6: Testing for Presence of Glucose

1. Add 10 drops of Benedict's solution to the unheated portion of the supernatant from Test 5.
2. Fill a second test tube one quarter full of water and add 10 drops of Benedict's solution (this is the control).
3. Boil both test tubes for 4 to 5 minutes and then allow test tubes to cool.
4. An orange precipitate will form when glucose is present.
5. Repeat with each sample.

Caution: Use care when working with Benedict's solution and a hot plate.

Part 2: Analyzing Unknown Urine Sample (Practice)

As practice, you will be required to complete an analysis of an unknown urine sample using the procedures you learned in Part 1.

1. Obtain 50 ml of one of the unknown urine samples.
2. Perform the urine analysis procedure on your unknown sample and compare the results to the known samples.
3. Check your results with the teacher's key.

Part 3: Analyzing Evidence from the Crime Scene

Repeat the procedures in Part 1 to analyze the evidence obtained at the crime scene.

Analysis

1. Do research to determine the normal ranges of the tests you have completed for human urine.
2. Pick one specific test and research the possible diseases or medical illnesses that can occur if a person exceeds the normal range.

ESSENTIAL UNDERSTANDING 12: ENRICHMENT AND EXTENSIONS—FURTHER ANALYSES

The types of evidence forensic investigators may analyze are seemingly endless. Along with many of the analyses outlined in the previous essential understandings, a forensic investigator may examine the following:

- **Teeth/Bite Marks**

  Teeth are the hardest substance in the body and tend to last the longest. They exhibit individual characteristics that allow dental impressions to be as reliable for identification as fingerprints. Teachers may choose to leave evidence, such as dental impressions on a foam cup, at the crime scene, and have students research investigative methods involved in the analysis of such evidence.

- **Radiation Half-Life**

  Half-life (for radioactive materials) represents the time required for a sample of radioactive material to "decay" to other isotopes such that half the original sample mass is still radioactive. For instance, if you were to say that a 10 gram uranium sample had a half-life of 500,000 years, after 500,000 years there would be 5 grams of radioactive uranium and the other 5 grams would be "stable" isotopes such as lead (Pb).

- **Lip Prints**

  A person's lip prints are unique, although the credibility of this type of evidence has not been firmly established. The basic types of lip prints used by forensic scientists are: branching grooves, short vertical grooves, long vertical grooves, diamond grooves and rectangular grooves. An activity similar to that of fingerprinting may be used in this unit. Chromatography might also be used on lipstick.

- **Ear Prints**

  As with lip prints, ear prints have characteristic patterns.

- **Footprints, Handprints, Knee Prints**

  Students can determine whether footprints, handprints, or knee prints are unique to each individual, and have value at a crime scene.

- **Weight**

  Students might determine weight from the depth of a print, similar to the determination of height.

- **"Trash Archeology"**

  Students analyze "garbage" to determine what information might be gained.

- **Glass Fragments**

  The type of glass and direction of impact can be determined by analysis of glass fragments (density, refractive index, fracture marks).

- **Dust/Dirt**

  An analysis of dust might link a suspect to a crime scene.

- **Pollen**

  Traces of pollen might link a suspect to a crime scene.

- **Paint**

  Paint can be examined and matched (using colour and gas chromatography).

- **Bullets and Cartridges**

  Bullets and cartridges have characteristic markings, which link them to a gun.

- **Voice Prints**

  A tape recording of a disguised voice might be compared against the voices of the suspects.

FINAL FORENSIC SCIENCES PERFORMANCE TASK: SAMPLE CRIME SCENE

The summative assessment example that follows was adapted from the classroom experiences of a Manitoba teacher implementing Forensic Sciences: A Crime Scene Investigation Unit. The scenario could be introduced at the outset as a unit organizer, or it could be used as a culminating set of student activities once the various forensic sciences principles and analyses have been developed as prior learning. The Final Forensic Sciences Performance Task Evaluation Rubric at the end of this activity provides one example of a selection of parameters that could be assessed.

Materials

Supply each investigative team with the following materials:

- latex gloves
- plastic zippered bags
- vials
- tweezers
- Evidence Sheets

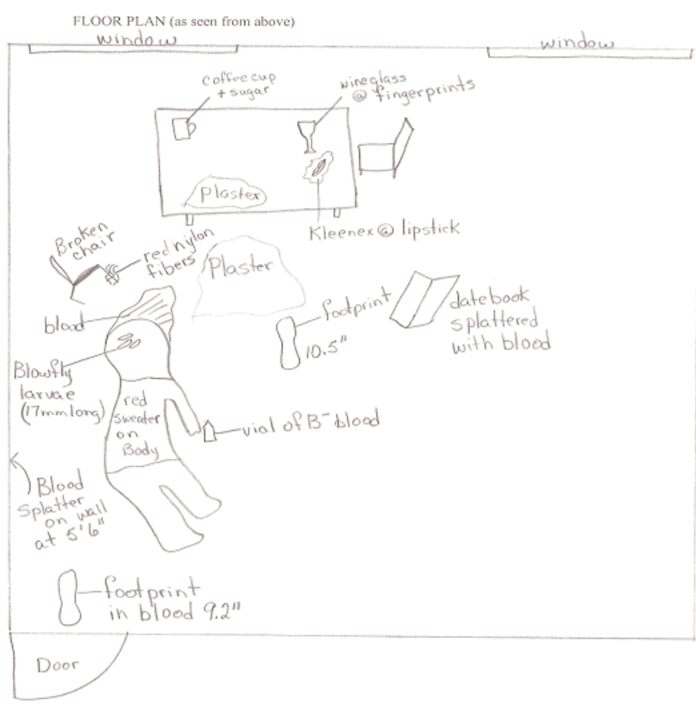
Also supply each team member with an identification tag that is to be worn around the neck on a string (business cards make good inserts).

Setting the Crime Scene

Students are expected to draw a detailed sketch of the crime scene, with key measurements, and take photographs with a digital camera. They then carry out appropriate forensic tests for the pieces of evidence that they gathered. Each team then reconstructs the crime scene and accounts for events in light of the evidence they gathered.

In the following sample, the teacher used an open classroom to set up the crime scene that took place in a cabin. It was taped off with crime-scene tape obtained from a local law-enforcement office.

Crime Scene Set Up



Forensic Sciences Performance Task: Sample Crime Scene: Adapted by permission of Brenda Sokoloski, Rivers Collegiate, Rolling River S.D.

Planting Evidence at the Crime Scene

1. **Date Book**
   - Splatter the date book with a simulated blood sample.
   - Make the following entries in the date book:
     - — June 24 – Marty 9 a.m.
     - — June 26 – Hammer 9 a.m.
– Summer 10 a.m.
     - — June 27 – Dentist 10 a.m.
     - — July 1 – Boo! Holiday Over

2. **Clothing Samples**
   - Give samples of the following clothing to the investigative teams.
     - — Suspects' clothing:
       - – Laura Cream-Fillet's skirt
       - – Michael Curtis Hammer's windbreaker
       - – George Fillet's cotton sweatshirt
     - — Victim's clothing:
       - – red sweater

3. **Lipstick Samples**
   - Use three different red pens to simulate lipstick samples on the chromatography paper.
   - Label each sample (and indicate to students that these were from lipstick that each had on her person):
     - — Marty Stewart
     - — Laura Cream-Fillet
     - — Diana Summer
   - Give samples of the lipstick found on the tissue to each investigative team for comparison purposes.
   - Place the pen used by Diana Summer on the tissue bearing the outline of a lip print.
   - Place this evidence on the table.

4. **Footprints**
   - Make two shoe prints:
     - — One print is from the suspect (stepping into the plaster), as found on the table. (Don't use too much of the mixture, as it can be messy.)
     - — The other print is found within the bloodstain.
   - Footprint lengths:
     - — plaster print is 10.5 in. (26.7 cm) long
     - — bloodstain print is 9.2 in. (23.4 cm) long

5. **Fingerprints**
   - Supply a set of fingerprints from all suspects *and* from the victim.
   - Put a set of fingerprints from Diana Summer on the wine glass.

   Note: Students may have difficulty lifting the print from the wine glass. Perfect this technique prior to this crime scene analysis for best results.

6. **Blood under Victim's Fingernails**
   - Leave a vial of simulated blood (B^-) at the scene near the outline of the victim's hand.
7. **Blowfly Larvae**
   - Using modelling clay, make blowfly larvae (17 mm long). Place them near the victim's eyeballs. This will indicate that the body has been dead for about five days. It would take the blowflies about a day to find their way into the cabin and start the decomposition through their feeding.
8. **Broken Chair**
   - Stick red nylon fibres in the blood on the leg of a broken chair. (Use an available disposable chair.)
9. **Blood Splatters**
   - Spatter blood on the wall in a pattern that spreads out from a height of about 5' 6" (1.7 m).
   - Pool blood around the area where the victim's head was situated.
10. **Plaster of Paris**
    - On the table, leave a small quantity of plaster and spill some on the floor where a footprint is found.
11. **Coffee Cup**
    - Place a coffee cup on the table. Inside the coffee cup, place a large quantity of sugar that has been in the coffee and left there. (It didn't dissolve.)

Conclusion:

The crime scene setup with the above evidence should direct suspicion towards Diana Summer (lipstick match, wineglass fingerprint, and footprint) and to Michael Hammer (footprint in plaster, plaster from a construction site, and sugar in the coffee cup). The red fibres belong to Michael Hammer's windbreaker. Both these suspects where scheduled to meet with John Bergman on June 26. The blood (B^-) under the victim's fingernails matches the blood type of both suspects.

The reconstruction of the crime may be open to interpretation, but students may come up with the idea that both Michael Hammer and Diana Summer met with John Bergman. The two suspects had drinks (wine and coffee). A fight broke out, and Bergman scratched and drew blood from Hammer. During the struggle, Summer hit Bergman with the chair, which knocked Bergman against the wall and splattered his blood on the wall. Bergman then fell to the floor and bled profusely. Fibres from Hammer's windbreaker stuck to the chair leg. The blowflies on Bergman's body indicate he has been dead about four to five days. He never made his dental appointment on June 27, as he died on June 26.

Evidence Sheet

Date:____________________ Time:_______________________ Exhibit #: _____

Description of the Evidence:____

Location of the Evidence: ____

Name and Description of the Test Performed: ____________________________

Conclusions: ____

Investigator's Signature: ____

Crime Scene Sketch

Victim and Suspect Background/Biographies

Victim	
Name: John Bergman **Occupation:** Construction contractor **Age:** 58 years **Height:** 6' 0" (1.83 m) **Weight:** 195 lbs. (88.5 kg) **Blood Type:** 0^- **Health:** Diabetic, but under control through diet and exercise	The victim's body was found on July 2, 2003, at 10 a.m. in his summer cabin at 1210 Lakeview Drive in Dullville, Ontario. Mr. Bergman often held meetings at his cabin for his clients and business associates. Mr. Bergman was very unpopular in the local town. He was the majority owner of the lakeshore property, and wanted to tear down most of the businesses there to make way for the construction of a massive new casino.
Description of the Body:	

Suspects	
Name: Michael Curtis Hammer **Occupation:** Carpenter and owner of M.C. Hammer Construction **Age:** 42 years **Marital Status:** Not married **Height:** 5' 10" (1.78 m) **Weight:** 215 lbs. (97.5 kg) **Blood Type:** B^- **Health:** Overweight from too many doughnuts, and lots of coffee with sugar and 30% cream	Michael Hammer is a local carpenter who has had many heated discussions with the victim regarding the proposed casino. If the casino was built, he would lose a great deal of business, and probably would have to declare bankruptcy. He now owes the bank over $100 000. Mr. Hammer is the brother of Mrs. Diana Summer. His usual work uniform consists of blue jeans, a pair of work boots, a light T-shirt, and a red rayon windbreaker.
Name: George Fillet **Occupation:** Dentist and local hotel owner **Age:** 38 years **Marital Status:** Married with two children, ages 12 and 14 **Height:** 5' 11" (1.80 m) **Weight:** 168 lbs. (76.2 kg) **Blood Type:** AB^+ **Health:** Good	George is the local dentist who could see that he would need to relocate his business somewhere else if the casino was built. Also, his marriage is in jeopardy, as his wife is unwilling to leave her town and feels very strongly that George is too soft to do anything about the casino. George usually wears his red cotton University of Guilt sweatshirt whenever he is not working. George claims that he could not have killed John Bergman because he worked all week. As a matter of interest, John missed his appointment on June 27 at 10 a.m.
Name: Diana Summer **Occupation:** Manager for Ontario Trust and Mortgages Co-Op **Age:** 39 years **Marital Status:** Divorced **Height:** 5' 3" (1.60 m) **Weight:** 120 lbs. (54.4 kg) **Blood Type:** B^- **Health:** Very good—she runs every day past John Bergman's cabin	Diana is the manager for the bank in town. John Bergman has been intimidating Ms. Summer for the past 12 months, trying to get her to approve loans in excess of $1 million for the building of the casino. Ms. Summer was to meet with Mr. Bergman on June 26 at his cabin, but she claims she never kept the appointment. The day in question she wore a grey wool dress and used her favourite lipstick when she went to work.

(continued)

Suspects *(continued)*	
Name: Laura Cream-Fillet **Occupation:** Works at the bakery and coffee shop on Wednesday and Thursdays **Age:** 35 years **Marital Status:** Married to George Fillet **Height:** 5' 7" (1.70 m) **Weight:** 122 lbs. (55.3 kg) **Blood Type:** B^+ **Health:** Good	Laura works at the local bakery every Wednesday and Thursday, and makes deliveries to the local businesses in the mornings. She can remember Mr. Bergman ordering doughnuts one of those days, either June 25 or 26. She can't quite remember. She delivered them to him at the cabin about 9 a.m. She was wearing her white smock and red polyester skirt, and was using her favourite lipstick. Laura can become very aggressive when angry. She has very strong feelings that the casino should not be built in her town.
Name: Marty Stewart **Occupation:** Interior designer with her own company **Age:** 51 years **Marital Status:** Divorced **Height:** 5' 1" (1.55 m) **Weight:** 150 lbs. (68.0 kg) **Blood Type:** A^+ **Health:** Borderline diabetic and arthritic in the hands	Mrs. Stewart had a meeting on June 24 with Mr. Bergman to discuss the interior decorating of the casino. Marty was late for the meeting, and a heated argument took place. The argument was loud enough that the neighbour, Mrs. Nosey, could hear. Mrs. Nosey said she remembers seeing Marty in her pink wool dress and wearing what looked like a pink lipstick. She wasn't quite sure about the lipstick colour though. Marty left very shortly after her arrival. She was obviously upset, as she spun her tires wildly when leaving the driveway.

Neighbour	
Mrs. Nosey	Mrs. Nosey is a very lonely individual who keeps track of her neighbours. She remembers Marty coming to the cabin on June 24. She says she also saw the doughnut truck that week. Later that week (can't remember which day) she remembers seeing someone enter the cabin about 9 a.m., and another enter the cabin at 10 a.m. Shortly after 10:30 a.m. there was a lot of yelling and furniture breaking inside the cabin. Right after that, the two people left the cabin and travelled in a blue car. One person was taller than the other, and Mrs. Nosey thinks one had a red coat or shirt on.

Final Forensic Sciences Performance Task: Evaluation Rubric

Total

Group Members: ______________________ ______________________

______________________ ______________________

Type of Project: ____

Forensic Investigation

Criteria	Rating				Total
	0	5	10	15	
Crime Scene Scenario					
• Creativity and originality					
• Development of evidence/clues					
• Development and documentation of suspect/victim background/biographies (e.g., fingerprints, footprints, hair samples, lip prints, bite marks)					
• Coherence of story/plot and alignment with evidence					
Paperwork					
• Materials list (crime scene supplies)					
• Detailed description (crime scene)					
• Diagram of crime scene (to scale)					
• Police reports on the crime scene (Evidence Sheet)					
• Quality of evidence descriptions					
• Photographs of crime scene					
• Forensic logbook					

Comments:

Student Self-Reflection on the Forensic Sciences Unit

Throughout our examination of the techniques, processes, and information-gathering activities of this Forensic Sciences unit, there has been an important emphasis on developing "essential understandings" about forensics and the manner in which science operates in the criminal justice system. Now that we have completed this unit of study, we will take time to look back and see what we have learned, identify lingering questions that were not answered for us, and then ask some new questions that have arisen in our minds.

In your *Forensic Investigation Lab Book* (or *Journal*), complete a one- to two-page self-reflection that addresses some of the thoughts and questions raised in the Forensic Sciences unit. Write freely and thoughtfully. You will then have an opportunity to discuss with your class what you are willing to share.

Here are some suggestions (framed as questions) to help you get started.

- What surprised you along the way as you developed understandings about the various forensic techniques used in the unit?
- Do you still have unanswered questions or are you wondering about some aspect of forensic sciences?
- What important things did you discover and learn about what it means to *be* a forensic scientist trying to solve a crime?
- Among the various forensic techniques that you worked through, which one(s) interested you most? Could you explain why?
- Were some forensic techniques challenging to master? If so, which one(s)? Explain why.
- Were you surprised at the amount of science that came out of your study of forensics? Did you have to apply a lot of this new knowledge right away in order to analyze evidence? Explain.
- How will your study of forensics change the way you view "prime time" forensic investigation shows or reports in the media about the work of forensic scientists?

RESOURCES

Print Resources

Bevel, Virgil Thomas, and Ross M. Gardner. *Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction*. CRC Series in Practical Aspects of Criminal and Forensic Investigation. Boca Raton, FL: CRC Press, 1997.

Bowers, Vivien. *Crime Science: How Investigators Use Science to Track Down the Bad Guys*. Toronto, ON: Owl Books/Maple Tree Press, 1997.

Coleman, Howard, and Eric Swenson. *DNA in the Courtroom: A Trial Watcher's Guide.* Seattle, WA: GeneLex Press, 1994.

Guiberson, Brenda Z. *Mummy Mysteries: Tales from North America.* New York, NY: Henry Holt, 1998.

Jackson, Donna M. *The Bone Detectives: How Forensic Anthropologists Solve Crimes and Uncover Mysteries of the Dead.* Boston, MA: Little, Brown, 1996.

Lane, Brian. *Crime and Detection.* New York, NY: DK Publishing, 2000.

Manitoba Education and Training. *Senior Years Science Teachers' Handbook: A Teaching Resource*. Winnipeg, MB: Manitoba Education and Training, 1997.

McCrone, Walter C. "Artful Dodgers*." The Sciences* (Jan./Feb. 2001): 32-37.
Chemical techniques involved in authenticating works of art.

Mellett, Peter. *Solving a Crime (Expert Guide).* Des Plaines, IL: Heinemann Library, 1999.
An illustrated story that follows the investigation of the theft of a museum artefact.

Otfinoski, Steven*. Whodunit? Science Involves Crime.* New York, NY: W.H. Freeman, 1995.
Case studies and the forensic science that solved them.

Ramsland, Katherine. *The Forensic Science of C.S.I*. New York, NY: Berkley Publishing Group, 2001.

Saferstein, Richard. *Criminalistics: An Introduction to Forensic Science.* 6th ed. Englewood Cliffs, NJ: Prentice Hall, 1998. 379-383.

Thomas, Peggy. *Talking Bones: The Science of Forensic Anthropology.* New York, NY: Facts on File, 1995.

Tocci, Salvatore, and Franklin Watts. *High-Tech IDs: From Finger Scans to Voice Patterns*. New York, NY: Franklin Watts, 2000.
The latest in forensic and other identifying technologies.

Walker, Pam, and Elaine Wood. *Crime Scene Investigation: Real Life Science Labs for Grades 6-12*. San Francisco, CA: Jossey-Bass, 2002.

Wilcox, Charlotte. *Mummies, Bones and Body Parts*. Minneapolis, MN: Carolrhoda Books, 2000.

Collecting Crime Evidence from Earth

Andrews, Sarah. "Fiction Meets Fact: A Visit to the FBI Lab." *Geotimes* 50.1 (2005): 20-21.

---. *Earth Colors.* New York, NY: St. Martin's Minotaur Press, 2005.
This is Andrews's ninth fiction novel in the mystery series featuring Emma Hansen, a forensic geologist. In this story, Hansen tackles pigment analysis and other techniques to determine whether a famous painting has been fraudulently reproduced. Meanwhile, someone is quietly poisoning her client's family members. This is one of many "page turners" that Andrews has written, including titles such as *Killer Dust* and *The Bone Hunter*, and all contain good, solid science.

Murray, Ramond C. "Collecting Crime Evidence from Earth." *Geotimes* 50.1 (2005): 18-22.

---. *Evidence from the Earth.* Missoula, MT: Mountain Press Publishing Co., 2004.
Looking for more background in the field of forensic geology? Murray's latest book follows up his earlier groundbreaking treatise *Forensic Geology* (1975). He connects some notorious and interesting cases where geology has provided key evidence from earth materials. The chapters detail collection methods, instrumentation used, examination methods, and the unique manner in which geological thinking helps to solve mysteries.

Sever, Megan. "Murder and Mud in the Shenandoah." *Geotimes* 50.1 (2005): 24-29.

---. "Forensic Geology on the Small Screen." *Geotimes* 50.1 (2005): 46-47.

Scientific Fraud

Abbott, David M. "Investigating Mining Frauds." *Geotimes* 50.1 (2005): 30-32.
In this article, Abbott—who was a geologist for 21 years working for the Securities and Exchange Commission in the U.S.—details examples of where geological knowledge was the binding tie in the line of evidence to uncover scientific fraud. He calls this "lying about the science for profit," and produces some little-known stories of how ore samples have been "spun" to yield analytical values that would be right out of Rumpelstiltskin.

Online Resources

A Comprehensive Forensic Sciences Site for Teachers and Students

Brandon School Division. Crocus Plains Regional Secondary School. Current Topics (30S). Forensic Science: <http://www.brandonsd.mb.ca/crocus/stafflinks/M/McKellar/currenttopics30S/forensics.htm>
This comprehensive website has been created and is maintained by Coleen McKellar, a Senior Years science teacher at Crocus Plains Regional Secondary School in Brandon MB. The site is organized around a wide variety of themes and topics of interest related to a study of Forensic Sciences in the Senior 3 Current Topics in the Sciences classroom. It is particularly valuable for students who are engaged in inquiry or project-related research, and saves the teacher a great deal of time in accessing reputable material for student use. Many of the activities in the Forensic Sciences sample unit are represented in the links that have been archived at this site.

Bloodstain Evidence

International Association of Bloodstain Pattern Analysts (IABPA):
<http://www.iabpa.org/index.html>
"Violent crimes can result in bloodshed. When liquid blood is acted upon by physical forces, bloodstains and bloodstain patterns may be deposited on various surfaces, including the clothing of the individuals present at the crime scene. When examined by a qualified analyst, these bloodstain patterns can yield valuable information concerning the events that led to their creation. The information gained can then be used for the reconstruction of the incident and the evaluation of the statements of the witnesses and the crime participants." (Home page)

Crime Scene Investigation

Crime Scene Investigation: <http://www.crime-scene-investigator.net/index.html>
This website offers information on evidence collection, crime scene and evidence photography, and articles on forensic investigations, along with listings of other resources and links.

Criminal Identification

Brazoria County Sheriff's Department. Identification Department:
<http://www.brazoria-county.com/sheriff/id/>
Information on blood spatters, fingerprints, forensic entomology, crime scene photography, crime scene searches, firearms, and skeleton identification.

Crime Scene Scenario: Who Done It?

The Woodrow Wilson National Fellowship Foundation. Woodrow Wilson Biology Institute. Who Done It? <http://www.woodrow.org/teachers/bi/1993/who.html>
Crime scene scenario by Liz Fulton, Carol Alderman, and Carol Sanders.

CyberBee. Who Dunnit? <http://www.cyberbee.com/whodunnit/crime.html>
Analyze a crime scene online and solve the crime.

DNA Detectives

Access Excellence @ the National Health Museum. 1995 Access Excellence Fellows' Collection. *DNA Detectives*.
<http://www.accessexcellence.org/AE/AEC/AEF/1995/black_dna.html>
Lab activity by Suzanne Black. "Many of the revolutionary changes that have occurred in biology over the past fifteen years can be attributed directly to the ability to manipulate DNA in defined ways. The principal tools for this recombinant DNA technology are enzymes that can "cut" and "paste" DNA. Restriction enzymes are the "chemical scissors" of the molecular biologist; these enzymes cut DNA at specific nucleotide sequences. A sample of someone's DNA, incubated with restriction enzymes, is reduced to millions of DNA fragments of varying sizes. A DNA sample from a different person would have a different nucleotide sequence and would thus be enzymatically "chopped up" into a very different collection of fragments. We have been asked to apply DNA fingerprinting to determine which suspect should be charged with a crime perpetrated in our city." (Introduction)

DNA Electrophoresis Technique

Southwest Biotechnology and Information Centre (SWBIC). Educational Resources. DNA Fingerprinting: Analysis of Crime Scene DNA: <http://www.swbic.org/education/crime.php>

---. Crime Lab Simulation: DNA Analysis with Agarose Gel Electrophoresis: <http://www.swbic.org/education/crime.doc>
A crime lab simulation that involves running a DNA analysis with agarose gel electrophoresis. Discover how the remarkable DNA electrophoresis technique has revolutionized our ability to analyze field evidence in the crime lab.

DNA Fingerprinting

Public Broadcasting Service (PBS). WGBH Educational Foundation. Nova Online. Killer's Trail. Create a DNA Fingerprint. <http://www.pbs.org/wgbh/nova/sheppard/analyze.html>

University of Washington. Basics of DNA Fingerprinting: <http://protist.biology.washington.edu/fingerprint/dnaintro.html>
Class project by Kate Briton and Kim-An Lieberman. "This page was created as a class project at the University of Washington to provide to the Internet basic information on the structure and function of DNA as it relates to DNA fingerprinting. This topic is especially pertinent in today's society because of the rising use of DNA fingerprinting as evidence in court cases."

Utah State University. Biomath Lab. DNA Fingerprinting Probabilities: <http://biomath.biology.usu.edu/Fipse/Labs/Dna/DownloadPage/DNAFINGE.pdf>
Statistical analysis of the accuracy of DNA fingerprinting.

DNA Workshop

Public Broadcasting Service (PBS). WGBH Educational Foundation. A Science Odyssey. DNA Workshop: You Try It: <http://www.pbs.org/wgbh/aso/tryit/dna/>
This activity places you within the cell, involving you with the processes of DNA replication and protein synthesis.

Facial Reconstructions

Forensic Art. Historical Exhumation Project. Facial Reconstruction: <http://www.forensicartist.com/hep/index.htm>

Fingerprints

Michigan State University. Biometrics Research. Fingerprint Identification: <http://biometrics.cse.msu.edu/fingerprint.html>

Onin Portal. Latent Print Examination. The History of Fingerprints: <http://onin.com/fp/fphistory.html>

Forensic Archaeology (Pompeii and Mount Vesuvius)

Educational Travel Alliance (eTrav) Inc. eTrav Pathways. Pompeii and Mount Vesuvius: <http://www.etrav.com/pathways/html/pompeii.asp>
Daily life in Pompeii and Herculaneum.

Health Portal. Herculaneum Meltdown:
<http://ipagehealth.subportal.com/health/Safety_and_Public_Health/110012.html>
This article by Neil Sherman addresses the causes of death from the eruption of Vesuvius.

Forensic Entomology

Forensic Entomology. Insects in Legal Investigations:
<http://www.forensic-entomology.com/index.html>

Forensic Entomology Pages, International:
<http://folk.uio.no/mostarke/forens_ent/forensic_entomology.html>

Royal Canadian Mounted Police. *Forensic Entomology: The Use of Insects in Death Investigations:* <http://www.rcmp-learning.org/docs/ecdd0030.htm>
Forensic entomology "is the study of the insects associated with a human corpse in an effort to determine elapsed time since death. Insect evidence may also show that the body has been moved to a second site after death, or that the body has been disturbed at some time, either by animals, or by the killer returning to the scene of the crime." (Introduction)

Forensic Geology

American Geological Institute (AGI). *Geotimes: Earth, Energy and Environment News:* <http://www.geotimes.org>
The collection of crime scene evidence related to the geosciences is an underappreciated source of cross-curricular linkages for science educators. Here is a comprehensive source of resources to capture interest in the role of earth as evidence.

Sarah Andrews. Forensic Geology: <http://www.sarahandrews.net>
Sarah Andrews is a geologist who has written nine novels as well as short stories that follow fictional forensic geologist Emma Hansen. Provides solid science and excellent role-modelling for young women aspiring to the fields of the geosciences.

Forensic Science

The Canadian Society of Forensic Science (CSFS): <http://www.csfs.ca/>
"The Canadian Society of Forensic Science (CSFS) is a non-profit professional organization incorporated to maintain professional standards, and to promote the study and enhance the stature of forensic science. Membership in the society is open internationally to professionals with an active interest in the forensic sciences. It is organized into sections representing diverse areas of forensic examination: Anthropology, Medical, Odontology, Biology, Chemistry, Documents, Engineering and Toxicology." (Home page)

Forensic DNA Consulting. Forensic Science Timeline: <http://www.forensicdna.com/>
Click on to Forensic Scene Timeline. You will need to set up a free online account by providing your name and a valid email address.

Forensic Science Web Pages: <http://home.earthlink.net/~thekeither/Forensic/forsone.htm>
These web pages were created to provide the layperson with an easy understanding of what forensic science entails, with brief explanations of some of the main disciplines within Forensic Science.

Forensic Services

U.S. Department of Justice. Federal Bureau of Investigation (FBI). *Handbook of Forensic Services:* <http://www.fbi.gov/hq/lab/handbook/intro.htm>
<http://www.fbi.gov/hq/lab/handbook/forensics.pdf>
"The purpose of the *Handbook of Forensic Services* is to provide guidance and procedures for safe and efficient methods of collecting and preserving evidence and to describe the forensic examinations performed by the FBI Laboratory." (Introduction)

Handwriting and Forensic Analysis

Courtroom Television Network LLC. Court TV's Crime Library:
<http://www.crimelibrary.com/forensics/literacy>
Enter the term "handwriting" in the search engine that appears at this site.

Mummification

Mummy Tombs. Mummymaking Methods:
<http://www.mummytombs.com/egypt/methods.htm>

The National Center for Supercomputing Applications (NCSA). Visualization Division. Cyber Mummy: <http://archive.ncsa.uiuc.edu/Cyberia/VideoTestbed/Projects/Mummy/mummyhome.html>

Public Broadcasting Service (PBS). WGBH Educational Foundation. Nova Online. Mummies of the World: <http://www.pbs.org/wgbh/nova/peru/mummies>

---. Reading the Remains: <http://www.pbs.org/wgbh/nova/icemummies/remains.html>

Mysteries

MysteryNet: The Online Mystery Network: <http://www.mysterynet.com>
Online solvable mysteries.

Osteology (Bone Science)

The eSkeletons Project: <http://www.eskeletons.org/>
The eSkeletons Project website enables you to view the bones of a human, gorilla, and baboon, and to gather information about them from the osteology database.

Pearson Education, Inc. Bone Review:
<http://occawlonline.pearsoned.com/bookbind/pubbooks/mariebhap/chapter7/custom4/>
Pictures and quizzes of bones of the human skeleton.

Simon Fraser University Museum of Archaeology and Ethnology:
<http://www.sfu.ca/archaeology/museum/alpha/search.htm>
This site outlines the numerous ways that bones and bone fragments reveal the past.

Spoilheap. Human Bones: <http://www.spoilheap.co.uk/hsr.htm>

Recovery of Shredded Documents

Webcom Pty Ltd. Chris Anderson & Co Pty Ltd. The Recovery of Shredded Documents:
<http://www.docexam.com.au/images/shred.htm>

Trajectory Motion Calculations

The Shodor Education Foundation, Inc. Forensic Science. Stapleton's Fall:
<http://www.shodor.org/succeed/forensic/fall.html>
Fall from window scenario involving trajectory motion calculations. The scenario is from Chain of Evidence by Ridley Pearson.

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