SECTION 1: MANITOBA FOUNDATIONS FOR SCIENCE LITERACY

MANITOBA FOUNDATIONS FOR SCIENTIFIC LITERACY

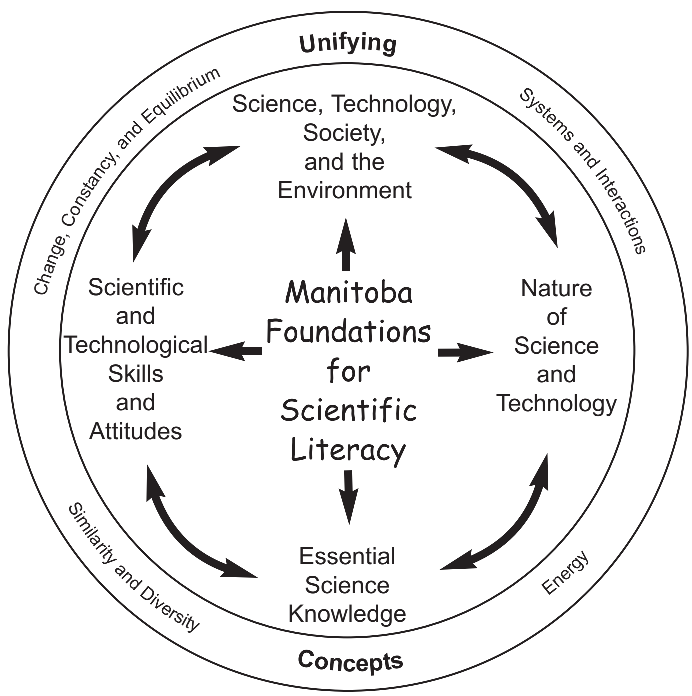
The Five Foundations

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.

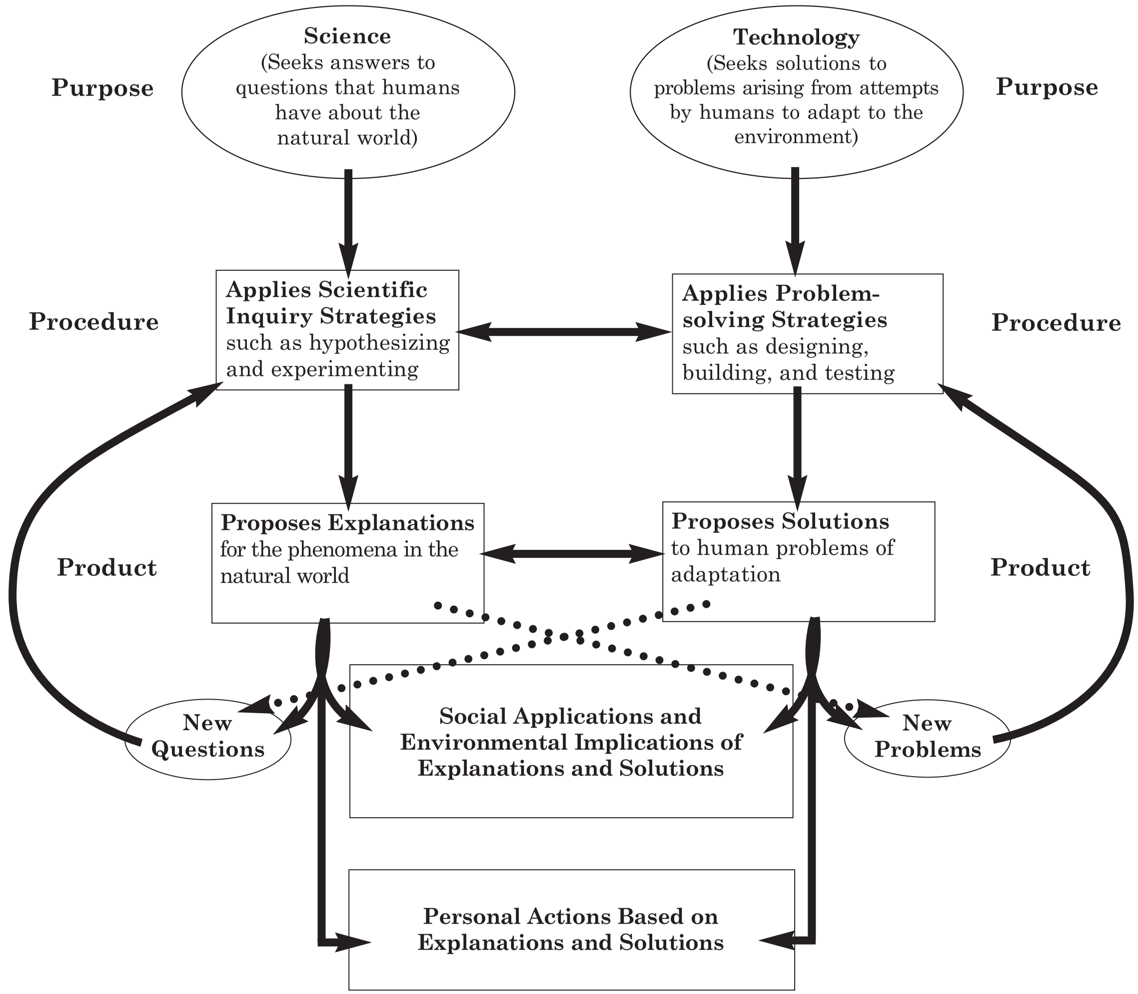
> Producing science knowledge is an intrinsically collective endeavour. There is no such thing as stand-alone science. Scientists submit models and solutions to the assessment of their peers who judge their logical and experimental soundness by reference to the body of existing knowledge (Larochelle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

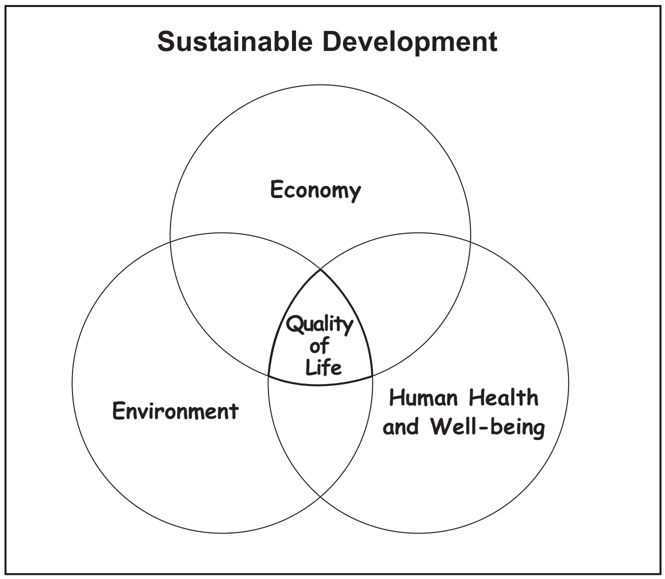
Scientific knowledge is necessary, but not sufficient, for understanding the relationships between science, technology, society, and the environment. To understand these relationships fully, it is essential that students consider the values related to science, technology, society, and the environment.

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.

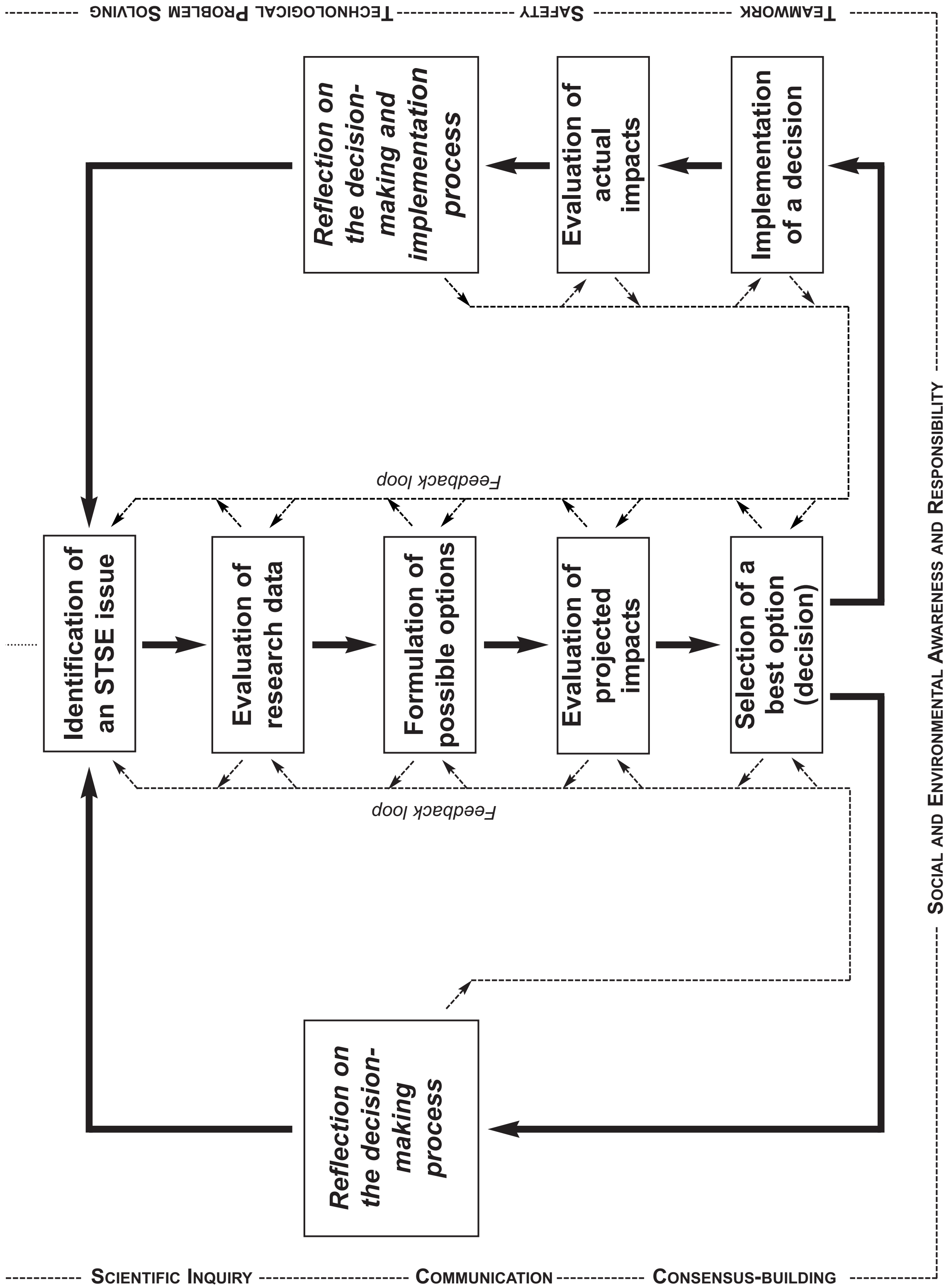
STSE Issues and Decision Making

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



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