IMPLEMENTATION OF SENIOR 2 SCIENCE

The Senior 2 Student and the Science Learning Environment

Each year, teachers make a myriad of decisions regarding course content, learning materials and resources, and instructional and assessment methods. Successful learning is more likely to occur if these decisions are informed by teachers' understanding of their students and the ways they learn.

Teachers seeking to learn about their students need to be knowledgeable in various areas, including the following:

- **How people learn:** In recent decades, cognitive psychology, brain-imaging technology, multiple intelligences theory, and constructivist learning theory have transformed our understanding of learning. Teachers need to engage in ongoing professional development and to update their knowledge of the processes of learning.
- **The ways in which student populations are changing:** The students whom 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.
- **The developmental characteristics of Senior 2 students:** The characteristics of adolescent learners, and the particular situation of Senior 2 students in middle adolescence, have many implications for teachers.
- **The unique qualities of each student:** Family relationships, academic and life experiences, personality, interests, learning approaches, rate of development, and language proficiency all influence a student's ability to learn. Teachers can gain an understanding of the unique qualities of each student through ongoing interaction, observation, and assessment.

Characteristics of Senior 2 Learners

If a symbolic line could be drawn between childhood and adulthood, it would be drawn for many students during their Senior 2 year. These students begin to assume many of the responsibilities associated with maturity. Many take their first part-time job. Many embark on their first serious romantic relationship. For many, acquiring a driver's licence is a significant rite of passage.

Although many Senior 2 students handle their new responsibilities and the many demands on their time with ease, others experience difficulty. Senior 2 can be a key year for at-risk students. External interests may seem more important than school. Because of their increased autonomy, students who in previous years 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. Being aware of what their students are experiencing outside school is important for teachers at every level.

Although the huge developmental variance evident in Grade 6 through Senior 1 is narrowing, students in Senior 2 can still demonstrate a development range of up to three years. Adolescents also change a great deal in the course of one year or even one semester. Senior 2 teachers need to be sensitive to the classroom dynamic, and recognize when shifts in interests, capabilities, and needs are occurring, so they can adjust learning activities for their students.

There are, however, some generalizations that can be made about Senior 2 students. The following chart identifies some common characteristics observed in educational studies (Glatthorn, 1993; Maxwell and Meiser, 1997) and by Manitoba teachers, and discusses the implications of these characteristics for teachers.

Senior 2 Learners: Implications for Teachers*

Characteristics of Senior 2 Learners	Accommodating Senior 2 Learners
Physical Characteristics	
• Some Senior 2 students, 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.
• Senior 2 students are able to sit still and concentrate on one activity for longer periods than previously, but still need interaction and variety.	• Put physical energy to the service of active learning, instead of trying to contain it. Provide variety; change the pace frequently; use kinesthetic activities.
• Many students come to school tired, as a result of part-time jobs or activity-overload.	• Work with students and families to set goals and plan activities realistically so that school work assumes a higher priority.

(continued)

* Adapted from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998) 4–6.

Senior 2 Learners: Implications for Teachers *(continued)*

Characteristics of Senior 2 Learners	Accommodating Senior 2 Learners
Cognitive Characteristics	
• Senior 2 learners are increasingly 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.
• 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 2, freeing students to concentrate on complex learning.	• Identify the skills and knowledge students already possess, and build the course around new challenges. Through assessment, identify students who have not mastered learning processes at Senior 2 levels, and provide additional assistance and support.
• Many students have developed specialized interests and expertise, and need to connect what they are learning to the world outside school.	• Encourage students to develop scientific literacy skills through exploring areas of interest. Cultivate classroom experts, and invite students with individual interests to enrich the learning experience of the class.
Moral and Ethical Characteristics	
• Senior 2 students are working at developing a personal ethic, rather than following an prescribed 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. They are often idealistic and impatient with the realities that make social change slow or difficult.	• Explore ways literacy 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.	• Provide opportunities for students to make and follow through on commitments, and to refine their interactive skills.
• Students have high standards for adult competency and consistency, and are resistant to arbitrary authority.	• Explain the purpose of every activity. Enlist student collaboration in developing classroom policies. Strive for consistency.

(continued)

Senior 2 Learners: Implications for Teachers *(continued)*

Characteristics of Senior 2 Learners	Accommodating Senior 2 Learners
Social Characteristics	
• Senior 2 students continue to be intensely concerned with how peers view their appearance and behaviour. Much of their sense of self is still drawn from peers, with whom they may adopt a "group consciousness," rather than making autonomous decisions.	• Ensure that the classroom has an accepting climate. Model respect for each student. Use language activities that foster student self-understanding and self-reflection. Challenge students to make personal judgements about situations in life and their natural environment.
• Peer acceptance is often more important than adult approval. Adolescents frequently express peer identification 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 sex can distract students from academics.	• Open doors for students to learn about science relationships through poetry, film, and fiction, and to explore their experiences and feelings in language. Respect confidentiality, except where a student's safety is at risk.
• Although Senior 2 students may have an aloof demeanour, they still expect and welcome a personal connection with their teachers.	• Nurture a relationship with each student. Try to find areas of common interest with each one. Respond with openness, empathy, and warmth.
Psychological and Emotional Characteristics	
• It is important for Senior 2 students to see that their autonomy and emerging independence is respected. They need a measure of control over what happens to them in school.	• Provide choice. Allow students to select many of the texts they will explore and the forms they will use to demonstrate their learning. Teach students to be independent learners. Gradually release responsibility to students.
• Students need to understand the purpose and relevance of activities, policies, and processes. Some express a growing sense of autonomy through questioning authority. Others may be passive and difficult to engage.	• Use students' tendency to question authority to help them develop critical thinking. Negotiate policies, and demonstrate a willingness to make compromises. Use student curiosity to fuel classroom inquiry.
• Students at this stage may be more reserved, aloof, and guarded than previously, both with teachers and with peers.	• Concentrate on getting to know each student early in the year. Provide optional and gradual opportunities for self-disclosure. Engage common interests in science-related hobbies through mutual interests.
• Students with a history of difficulties in school may be sophisticated in their understanding of school procedures, and resistant to efforts to help.	• Learn to understand each student's unique combination of abilities and learning approaches. Select topics, themes, and learning opportunities that offer students both a challenge and an opportunity to succeed. Make expectations very clear.
• Senior 2 students have a clearer sense of identity than they have had in previous years, and are capable of being more reflective and self-aware.	• Allow students to explore themselves through their work, and celebrate student differences.

Fostering a Will to Learn—Linking Language and Scientific Literacy

All literate individuals have moments of deep concentration when they lose themselves in the world of a text, or moments of satisfaction and pleasure in using language to express themselves forcefully and with precision. Experiences like these nurture a commitment to literacy. Ideally, the learner pursues every learning experience for its own sake, and will value improved scientific literacy.

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 (1997) 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 both to teach students how to read, write, and use science-related language in novel ways, 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. Teachers can promote certain attitudes and skills 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 (1987) 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 Motivation*

Ways to Foster Expectations of Success	Best Practice and Research
• Help students to develop a sense of self-efficacy.	• Schunk and Zimmerman (1997) 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 a sense of self-efficacy first 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. Second, teachers foster student self-efficacy by recognizing that each student can succeed, and communicating that belief to the student. Silver and Marshall (1990) 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.
• 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 (1997) 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, modeling, and practice so they can complete the tasks successfully.	• A methodology for thorough instruction of learning strategies is found on pages 37 and 38 of this overview.
• Help students to set specific and realistic personal goals and to learn from situations where they do not attain their goals, and celebrate student achievements.	• Research shows that learning is enhanced when students set goals that incorporate specific criteria and performance standards (Foster, 1996; Locke and Latham, 1990). Teachers promote this by working in collaboration with students in developing assessment rubrics (see Appendix 5: Developing Assessment Rubrics in Science).

* Reproduced from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998) 8–9.

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 texts, topics, activities, and creative forms. 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 scientific literacy to the richness and effectiveness of students' lives, and de-emphasize external rewards and consequences such as marks.
• Ensure that scientific literacy experiences are interactive.	• A community that encourages students to share their learning with each other values literacy. Teachers who model curiosity, enthusiasm, and pleasure in books, films, and other texts related to science and who share their own reading, writing, and experiences, foster motivation for scientific literacy learning.

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.

Ways to create a stimulating learning environment include the following:

- Designing seating arrangements that reflect a student-centred philosophy and that lend themselves to flexible grouping. Moveable tables or desks allow students to interact in various configurations. Desks arranged in a circle for whole-class discussions convey the importance of each speaker.
- Maintaining a media-rich environment. Having a school library does not preclude the need for a classroom library of books for self-selected reading. The classroom library may include science periodicals, newsletters, teen magazines, 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 exams collated into binders, and manuals. The reference area of the classroom may be designated as an editing station.

- Providing access to a computer, television, video cassette recorder, and CD/DVD-ROM, if possible.
- Exhibiting 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.
- Displaying items and artifacts, such as plants, photographs, art reproductions, maps, newspaper and magazine clippings, fossils, and musical instruments, to stimulate inquiry and to express the link between the science classroom and the larger world.
- Posting checklists, processes, and strategies to facilitate and encourage students' independent learning.
- Providing a bulletin board for administrative announcements and schedules.
- Involving students in classroom design.
- Providing interaction with animals (e.g., emphasizing zoological displays, providing aquariums).

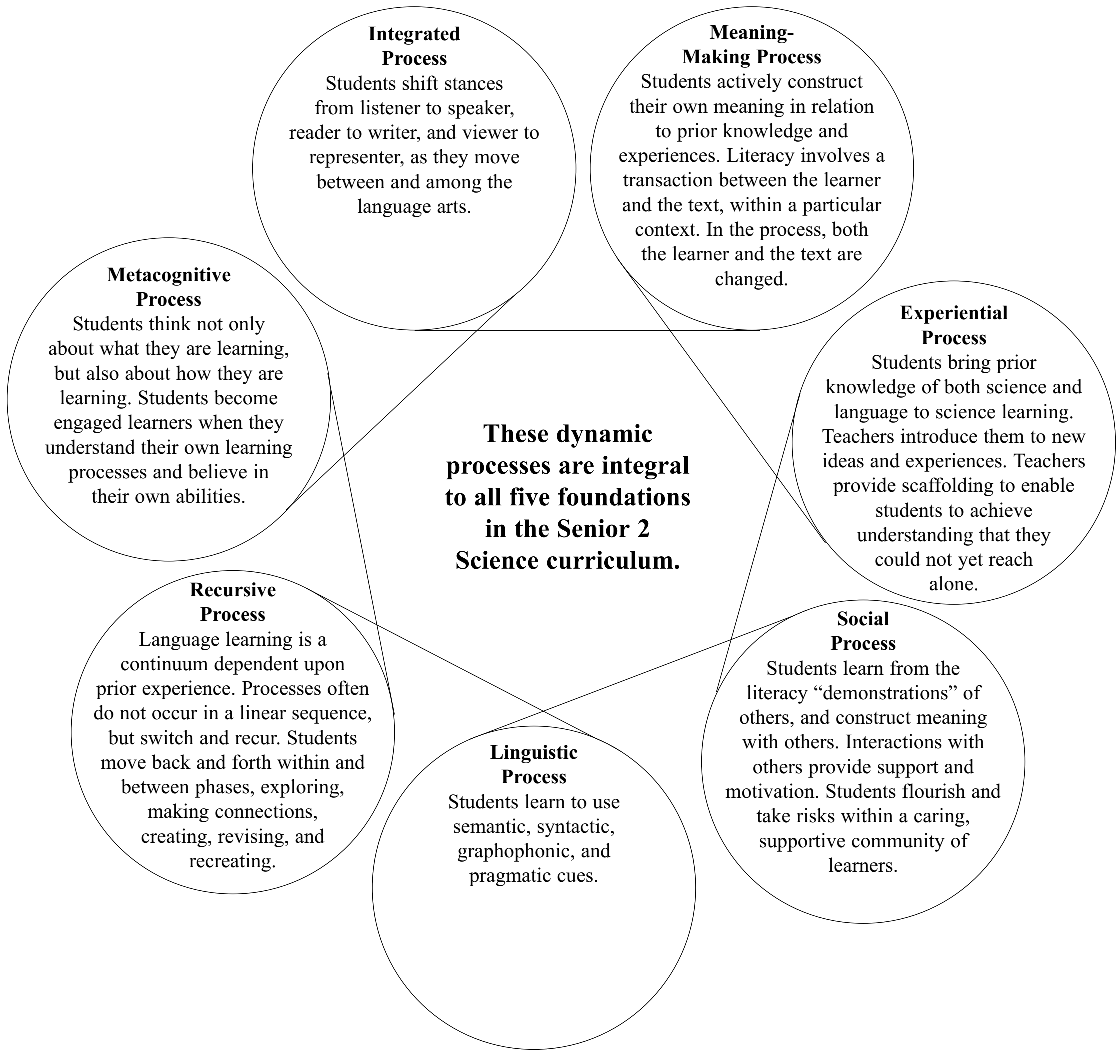
Language Learning Connected to Science

Science curricula involve all aspects of language and literacy development. Halliday (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 language arts and the role it has when applied to science.

Scientific literacy learning is dynamic and involves many processes. The following chart 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



Diversity in the Classroom

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. Some entry-level knowledge held by students may be limited or incorrect, impeding new learning. For new learning to occur, it is important for teachers to activate prior knowledge, correct misconceptions, and encourage students to relate new information to prior experiences.

Manitoba's cultural diversity provides opportunities for embracing a wealth of culturally significant references and learning resources in the Senior Years science classroom. 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 Teachers' Handbook* (hereinafter 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).

Toward this end, *Senior 2 Science: A Foundation for Implementation* acknowledges and supports cultural diversity. Included in this document are a range of instructional strategies and conceptual links to appropriate communities and their resources (e.g., Aboriginal communities, agricultural communities). 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 represented in the Senior Years classroom.

Instructional Philosophy

The learning environment should employ a variety of instructional strategies that include the collection and analysis of data from both laboratory and outdoor observations (especially in the case of the biodiversity and weather components), fieldwork, the use of living organisms in a caring manner, group and individual instruction, a diversity of questioning techniques, a focus on current major issues, and a resource-based approach to learning. Senior 2 science programming should foster critical thinking skills and promote the integration of knowledge and application of facts to real-life situations.

In general, science should be taught as a way of thinking that has rules for judging the validity of answers applicable to everyday life. Science should be portrayed as 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 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. Social, historical, and political implications must be included, with an opportunity for students to develop a facility to communicate ideas effectively through verbal and written expression. Finally, students should be provided with an opportunity to develop an awareness of the options available to them for careers and vocations in the wide diversity of sciences.

Ethical Issues

For many students and teachers, the study of scientific concepts may lead to issues and questions that go beyond the traditional curriculum. 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, raise questions of ethics, values, and responsible use of industrial products. These are among the important issues about which science is often called upon for advice. The environmental consequences of the industrial applications of chemistry or climate change raise issues of considerable merit. Due to the fact that these issues are derived from the study of science, they should be addressed, but it must be made clear to students that science only provides the background for (what is hoped will be) informed personal and social decisions. Teachers must handle these questions with sensitivity and clarity of purpose.

Concerns may be expressed by some students and parents because the evolutionary perspective of modern life science conflicts with personal beliefs. These individuals have a right to expect that science and the educational system will respect those beliefs. Teachers should explain to students that science is only one way of learning about the universe and our unique place embedded in it, and that other explanations, in addition to those of the traditional western sciences, have been put forth.

In some cases, individual teachers may choose to discuss alternative viewpoints on these matters with their science classes. However, because these viewpoints are not derived from the disciplines of science, they are not addressed directly in the science curriculum.

The Responsible Use of Animals in the Science Classroom

The curriculum encourages science teachers to foster a respect for life and to teach about the interrelationship and interdependency of all living things. Furthermore, a stewardship approach emphasizes that humans must care for the fragile web of life that exists on this planet.

The use of live animals and the dissection of animals is a well-established practice in the teaching of life sciences in particular. Well-constructed learning activities conducted by thoughtful teachers can illustrate important and enduring principles in the life sciences. However, teachers must carefully consider the educational objectives and available alternatives before using animals in the classroom.

Interactive multimedia materials such as computer simulations, tutorials, videodiscs, and videotapes can substitute for the use of animals in the classroom. However, these alternatives must satisfy the objectives of teaching scientific methodology and fundamental biological concepts. If, in the judgment of the teacher, available alternatives do not meet these objectives, dissection may be used, provided that no student is forced to participate. In the event that a student chooses not to participate in a dissection, the student is to be given assignments of comparable complexity and rigour.

Implementing alternative methods does not mean excluding animals from the classroom. Certain instructional strategies allow for the continued use of animals but with a modified approach (e.g., observation in behaviour studies and experimentation with invertebrates). In these cases, prudent and responsible use of these animals is essential.

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 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 2 Science (20F) 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/periodicals, films, audio and video recordings, computer-based multimedia resources, the Internet, and other materials. While a teacher may choose to use a particular text as a primary resource, we encourage teachers to model the use of various resources for their students.

Resources referenced in this curriculum include two recommended textbooks, student learning activities outlined in a set of appendices, multimedia learning resources, and other print reference material such as *Senior Years Science Teachers' Handbook: A Teaching Resource* (Manitoba Education and Training, 1997) and *Science Safety: A Kindergarten to Senior 4 Resource Manual for Teachers, Schools, and School Divisions* (Manitoba Education and Training, 1997). Recommended learning resources for Senior 2 science are listed in Senior 2 Science Learning Resources: *Annotated Bibliography*, available online at <http://www.edu.gov.mb.ca/ks4/learnres/science/s2scbib.pdf>.

The choice of textbook(s) and multimedia learning resources, including video, software, CD-ROMs, microcomputer-based laboratory (MBL) probeware, calculator-based laboratory (CBL) probeware, and the Internet, will depend on the local situation, reading level of the 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. Not all curricular outcomes can be achieved by using any one text as some topics require using other references or supports.

Using This Curriculum Document

This curriculum, consisting of four thematic clusters and one skills and attitudes cluster, is designed to build on what students know and are able to do as a result of their studies in Kindergarten to Senior 1 science.

Teachers are asked to be sensitive to the varying backgrounds of their students and to adapt instruction as necessary. Clusters do not need to be taught in the same sequence as they appear in the document. For example, it may be advantageous to document biodiversity in the spring or fall. Teachers should use their own discretion to provide opportunities for students to achieve learning outcomes in contexts that differ from those presented in this curriculum document. In all cases, however, the foundations, themes, and interdisciplinary nature of science should be emphasized.

Senior 2 Science (20F) provides a solid foundation for further study of Senior Years science courses and has a multidisciplinary focus. Accordingly, the curriculum includes topics that are deemed to be relevant to students' needs and interests, or are prerequisites to the further study of science at the Senior Years level.

Senior 2 Science (20F) assumes 110 hours of instructional time (see Scope, Sequence, and Time Allotments that appear with each Specific Learning Outcome or cluster of outcomes). Some time may need to be allocated to reviewing material from the appropriate sections of the Grades 5–Senior 1 curricula, but formal review of previous years' work is to be avoided. Teachers need to use a variety of strategies for activating prior knowledge to determine appropriate learning strategies for their students.

Preparing a Lesson

The format of *Senior 2 Science: A Foundation for Implementation* allows teachers to view the four major columns, namely **Prescribed Learning Outcomes, Suggestions for Instruction, Suggestions for Assessment,** and **Suggested Learning Resources.** The learning outcomes in the first column should guide teachers to make relevant decisions about instruction, assessment/evaluation, and appropriate learning resources. The document also contains Cluster 0 outcomes (Overall Skills and Attitudes) in **Prescribed Learning Outcomes.** These are based on the suggestions made for instruction. **Suggestions for Instruction** provides possible avenues or actions for student learning. Teachers should use their own professional judgment when deciding which strategies to use. It is NOT intended that teachers use all the suggested strategies. **Suggestions for Assessment** outlines a number of possible strategies beyond simple pencil-and-paper testing. Resources to support the prescribed outcomes are detailed in the final column, **Suggested Learning Resources.** It is hoped that this format will provide a useful "map" for teachers (i.e., a clear indication of what students are to know and be able to do, as well as a resource for strategies and materials to help students achieve these learning outcomes).

Science curricula in the past have been primarily focused on presenting a breadth of knowledge (i.e., a large amount of content) deemed essential. While this curriculum continues to be concerned with students acquiring relevant knowledge, it is also equally concerned both with fostering the development of various skills (context-based process skills, decision-making skills, problem-solving skills, laboratory experimental skills, critical-thinking skills, independent learning skills), and with effecting a change of attitude. In broad terms, these learning outcomes describe what we expect students to know and be able to do as a result of their studies.

In many instances, the **Suggestions for Instruction** columns begin by describing the probable **Entry-Level Knowledge** of students based on studies cited in previously published Manitoba curricula. Teachers are encouraged to determine entry levels of their students and select or develop approaches and materials to enable each student to achieve success. Many educators believe that time spent at this task has the greatest effect on student learning.

Senior 2 Science (20F) is driven by learning outcomes and process rather than by a single textbook. This design empowers teachers to plan appropriate learning experiences based on the nature of their students, school, and community. We encourage teachers to seek their own comfort level with the curriculum, to share approaches and experiences with colleagues, and to use it to develop and extend student experiences and understandings in new ways.

Promoting Strategic Learning

Many of the language tasks science students perform are problem-solving tasks, such as finding sources of information for an inquiry project, making meaning of a difficult text, or organizing a body of information. 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.

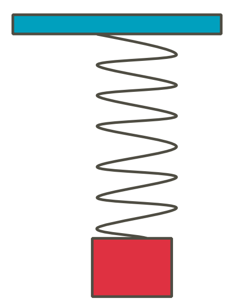
Strategic learners in the sciences need to have not only a strategic mindset, but also a repertoire of strategies for making meaning, for processing information, and for expressing ideas and information effectively. Whereas *skills* are largely unconscious mental processes that learners use in accomplishing 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."

Immersing students in language-rich environments and encouraging them to produce texts are essential in language learning, but these initiatives alone are not sufficient to ensure the development of proficient scientific literacy skills in all students. Students need methodical instruction in the strategies that adept learners use in approaching science tasks. The four-column section of this document includes numerous learning, teaching, and assessment strategies, and identifies professional resources that present additional strategies and approaches.

The Modes of Representation

Visual Mode

To illustrate these modes of representation, consider an example. A 0.5-kg mass is suspended from a spring (Figure 1). If we suspend a 1.0-kg mass and a 1.5-kg mass from identical springs, we perceive the relationship between the force that acts on the spring and the stretch of the spring. This is what we would call the visual mode of representing a relationship. Its basis is in the "real" world and our perceptions of this world.



In the visual mode we formulate a relationship between two variables and then test our hypothesis by observation and experimentation. As the force increases, the stretch increases. Sometimes, we can even determine the exact relationship. In this case, since the masses in Figure 1 line up in a straight line, the applied force and stretch must increase in some predictable proportion. Figure 2 shows how the visual mode can be applied to tracking a hurricane over time.

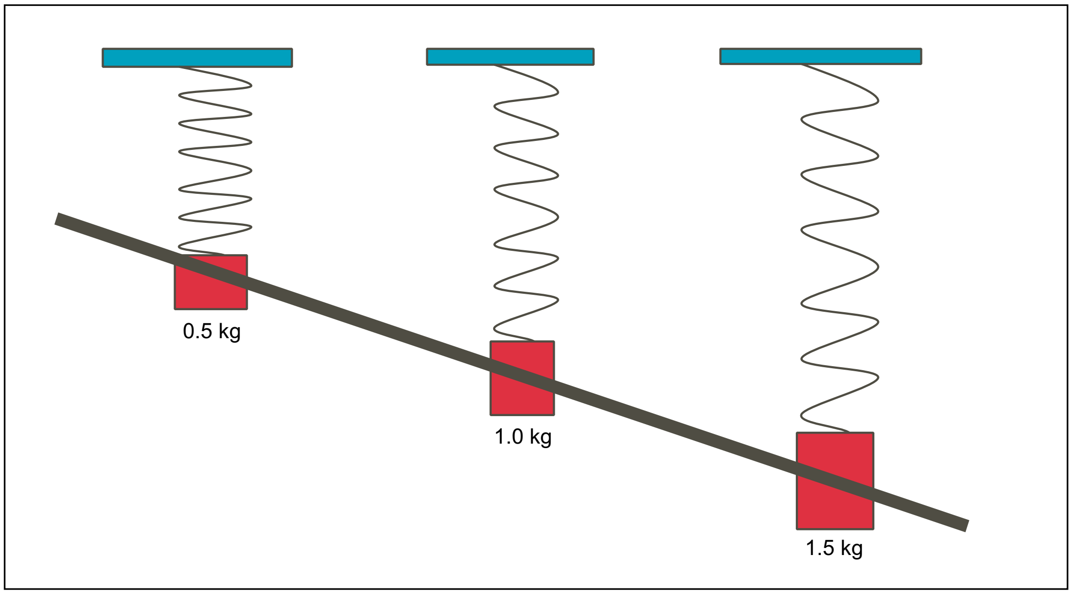
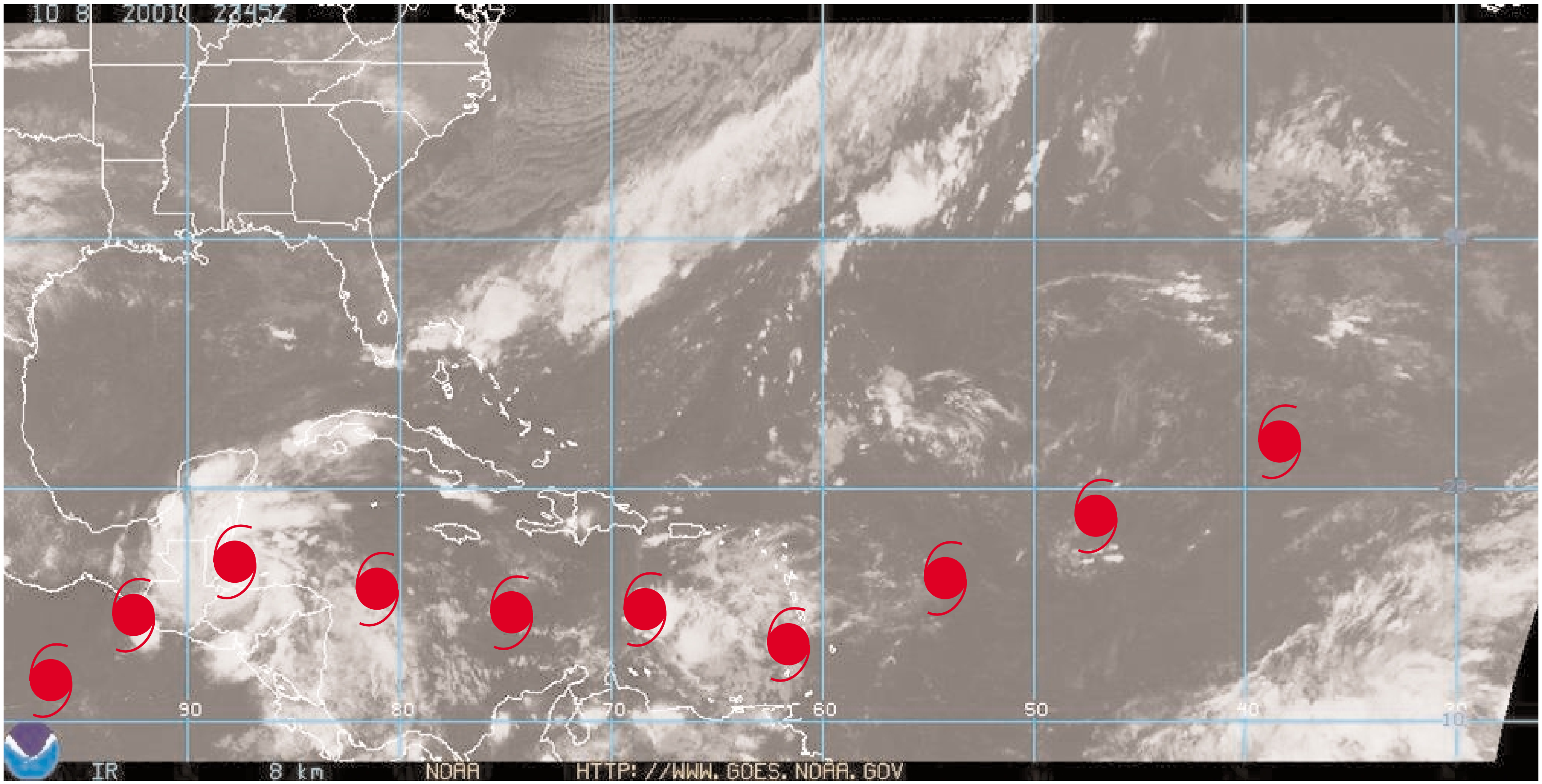


Figure 1

The visual mode embodies more than conjecture and observation. It incorporates critical and creative thinking as we build and modify models of nature that act as a foundation for our investigations. The "real" world is conceptualized by a set of guiding assumptions we imagine to be true. We may internalize a model to aid this conceptualization, and then we test this model using experiments. A successful model has explanatory and predictive capabilities. A model may incur discrepant events, which may force us to reconsider and modify our model. Our model may be falsified, in which case we abandon the model in search of a more complete and accurate model. For instance, the model of electric charge provides a foundation for the examination of electric phenomena. Historically, the fluid and particle models of charge accounted for experimental observations. However, as our ideas about the structure of matter evolved, the particle model provided a more reliable, predictive, and robust explanatory model.

Although we can make some general descriptions of relationships (as force increases, stretch increases), we cannot always determine an exact relationship, using the visual mode of representation. Therefore, we quantify the characteristics and compare the numbers. This is called the numerical mode of representation.



Satellite image courtesy of NOAA.

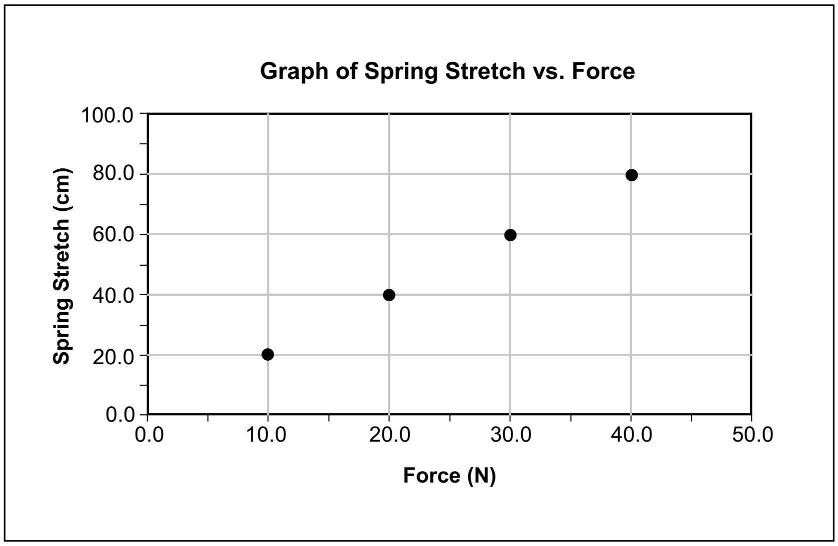
Numerical Mode

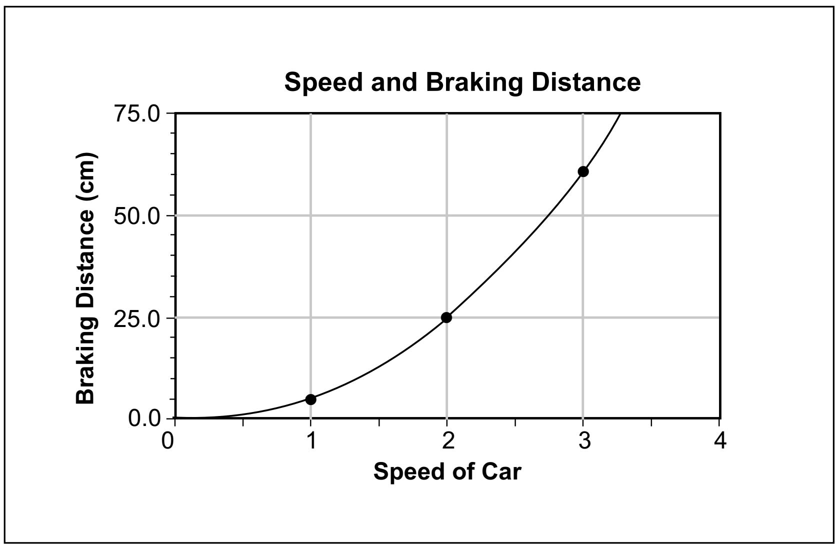
In the numerical mode of representation, we operationally define fundamental properties and use measurement to collect data. We can then examine the data to determine an exact relationship. The numerical mode dictates an understanding of proportioning and numerical patterns (e.g., if F doubles, X doubles, and if F triples, X triples). This suggests a direct proportion, and we can formulate our law. However, in most cases, the collection of data results in systematic errors. Determining the relation by inspection of the data can be very difficult. A picture, however, is worth a thousand numbers. Graphing the data usually gives a clearer picture of the relationship. It could be looked upon, for students, as a preparation for examining closely a "picture of the numbers."

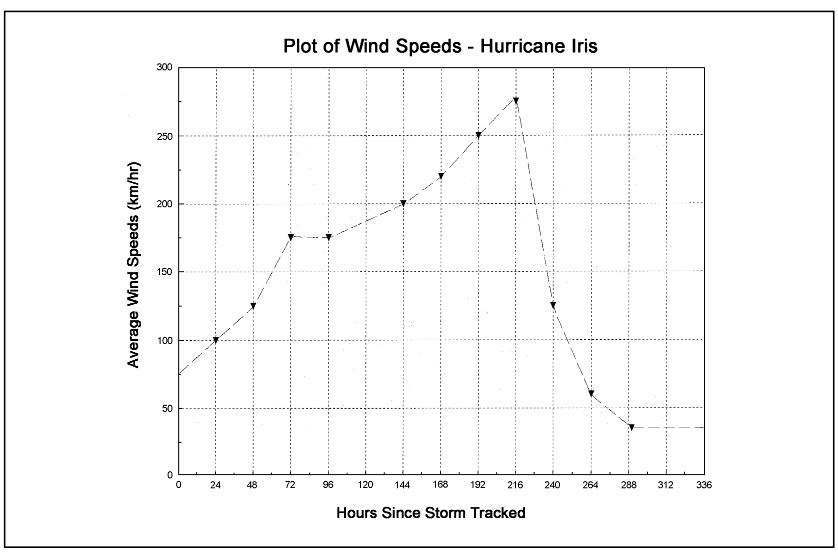
F (*N*)	X (*m*)
5.0	0.2
10.0	0.4
15.0	0.6
20.0	0.8

Graphical Mode

The graphical mode of representation is a mathematical picture of the relationship. Fortunately, there are a limited number of pictures one needs to know to determine relationships. In fact, at the introductory Senior 2 Science level, it is only necessary to know three pictures: a straight line, a power curve, and an inverse curve. At Senior 2, only linear relationships are treated quantitatively. Other relationships are examined qualitatively and do not require analytical techniques. By adjusting the data to "straighten the curve," we can determine the exact relationship and formulate a law that can be represented in a symbolic manner. At Senior 2, this level of treatment is considered optional. Ability to express the nature of a relationship in a "storytelling," qualitative manner is considered optimal for most students. Samples of graphical representations appear on the next page.


Graph of Spring Stretch vs. Force
Spring Stretch (cm)
100.0
80.0
60.0
40.0
20.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
Force (N)

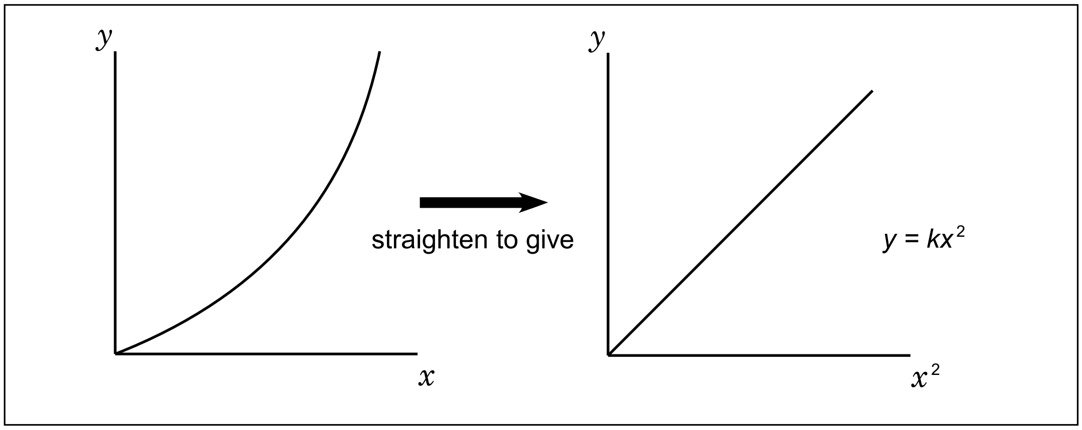

Speed and Braking Distance
Braking Distance (cm)
75.0
50.0
25.0
0.0
0
1
2
3
4
Speed of Car


Plot of Wind Speeds - Hurricane Iris
Average Wind Speeds (km/hr)
300
250
200
150
100
50
0
0
24
48
72
96
120
144
168
192
216
240
264
288
312
336
Hours Since Storm Tracked

Symbolic Mode

The fourth mode of representation is the **symbolic mode.** We represent the relationship as an algebraic formula, which can be applied to other physical events that are similar in nature.

For instance,



Therefore, we can represent relationships in four different modes: visual, numerical, graphical, and symbolic. In this model, students are able to function in each mode to demonstrate complete understanding and mastery of a concept.

The Importance of the Modes of Representation

It is easy to become caught up in a single mode, especially the symbolic, when it comes to the teaching and learning of physical concepts (e.g., motion). Students memorize equations and notation, learn to substitute for variables, and arrive at numeric solutions.

Meaningful connections between the symbolic and physical/conceptual modes are difficult to make in a decontextualized setting. Students taught exclusively in the symbolic mode often know how to arrive at “cookbook” answers, but they rarely understand or retain any of the concepts.

Students need to develop their understanding of relationships more completely, and develop skills in each mode of representation. Students should be able to transfer between modes both fluidly and with facility. Moving through the modes is not necessarily done in order. A “real scientist” can begin investigations in any mode and transfer easily through any combination of modes. Students who demonstrate a complete understanding of physical/conceptual relationships should be able to move from mode to mode in any order.

While fluency with the modes of representation provides a solid foundation for physics education, it is, of itself, not complete when it comes to portraying the nature of scientific activity. Albert Einstein, while developing his theory of relativity, conceptualized an hypothesis and then deduced a series of laws symbolically from a set of fundamental assumptions about time and space. He left it to others to observe, then refute or confirm his propositions. Historical perspectives, and an understanding of the nature of science, will move students toward a more philosophically valid treatment of physics.

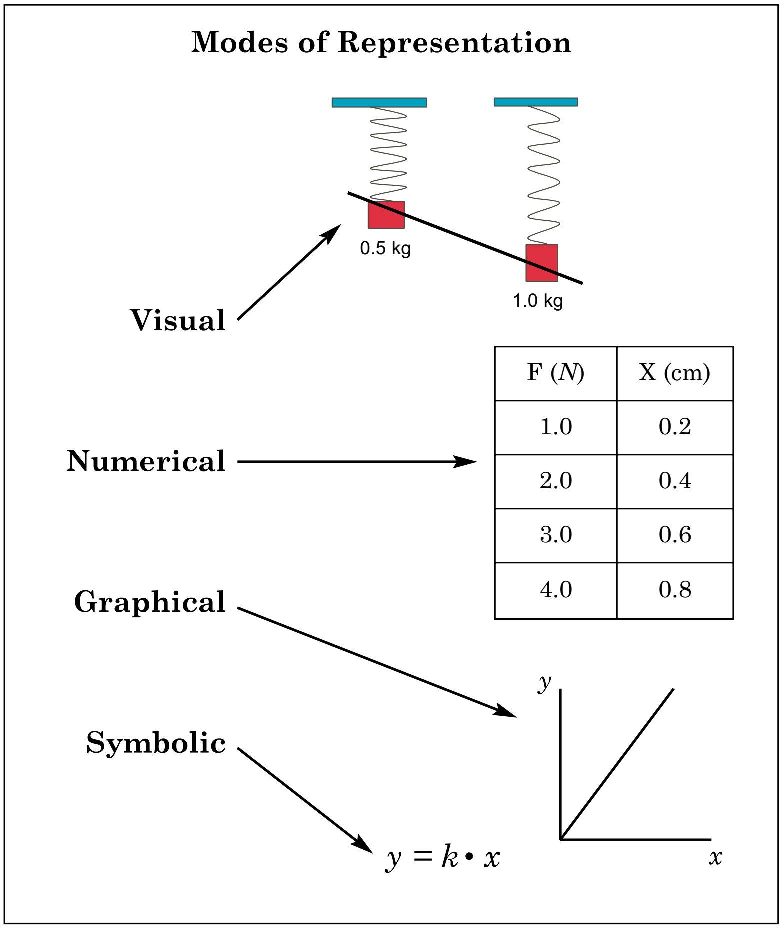
To Sum Up the Modes of Representation for Senior 2 Science Teachers

Visual: encourage students to discuss the representations they see and experience

Numeric: use student-generated measurements, always in the context of activities

Graphical: carefully plot graphs; get the "picture of the numbers," not "this is a picture of the world"

Symbolic: emphasize the concept first, then initially apply formulas as word definitions; only then work "type" problems using formulas; ideally, formulas are memorized only in certain instances



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

Scaffolding: Supporting Students in Strategic Learning

Many scientific literacy 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 (1996) 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,” based on the work of Wood, Bruner, and Ross (1976). 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
- modeling steps
- providing sufficient guided and independent practice

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 (e.g., 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.

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* Ideas and strategies for differentiating instruction are provided in *Success for All Learners* (Winnipeg, MB: Manitoba Education and Training, 1996) and in the *Senior Years Science Teachers’ Handbook* (Winnipeg, MB: Manitoba Education and Training, 1997).

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 prescribed student learning outcomes is to differentiate the instructional strategies (see *Success for All Learners,* Manitoba Education and Training, 1996). 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 attitudes to students' daily lives
- challenge students to realize academic and personal progress and achievement

Differentiating instruction does not mean offering a different program 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.

Learning Phases

Differentiated instructional strategies can be used in relation to the three learning phases:

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

These phases of learning are not entirely linear, nor are they discrete; rather, they provide teachers with a useful way of thinking and planning.

- The activating phase helps identify students' prior knowledge.
- The acquiring phase helps students to integrate new information with what they already know, adding or revising their previous knowledge as needed. Teachers help students make meaning of new information.
- The applying phase allows students to reflect on what they have learned, apply their learning to new situations, and extend their learning by drawing connections to other subject areas.

For a discussion of these three learning phases, see Chapter 6 of *Success for All Learners*.

Senior 2 Science: A Foundation for Implementation includes cross-references to *Success for All Learners* and *Senior Years Science Teachers' Handbook (SYSTH)*. Teachers can refer to these documents for further information. Strategies that can be used effectively in the Senior Years science classroom include graphic organizers (such as mind maps), knowledge charts that use students' prior knowledge, collaborative activities in brainstorming for solutions to design problems, information-processing strategies, science learning logs, and many others. The following list outlines instructional strategies that can be used with this *Senior 2 Science: A Foundation for Implementation*.

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* Adapted from Manitoba Education and Training, *Senior 2 English Language Arts: A Foundation for Implementation* (Winnipeg, MB: Manitoba Education and Training, 1998).

Instruction

- **Entry-Level Knowledge**
  — Entry-level knowledge summarizes prior content knowledge that students may have obtained in earlier grades, other courses, or through personal experiences. Activating this knowledge can be a powerful tool, as students organize and make meaning of new ideas, experiences, and information in connection with their prior knowledge.
- **Notes for Instruction**
  — Notes for instruction outlines the depth and breadth to which learning outcomes are to be addressed. Definitions, safety concerns, and teaching/learning suggestions may also be included.
- **Student Learning Activities**
  — A number of instructional strategies involving student engagement with learning materials are available for each learning outcome. Deciding which learning activities to use is an important part of a teacher's initial planning process. To successfully address each learning outcome of the curriculum, teachers need to make deliberate, informed decisions about the best tools to use for each learning task, given the particular needs and characteristics of their students.
- **Journal Writing**
  — Science journal writing allows students to explore and record all aspects of their science class experiences. By sorting out their thoughts on paper or thinking about their learning (metacognition), students process more deeply what they are learning.
- **Class Discussion**
  — Discussions can be used in a variety of ways. They can 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.
- **Prior Knowledge Activities**
  — Students learn best when they can relate new knowledge to what they already know. Brainstorming, KWL charts, and Listen-Think-Pair-Share are just a few of the strategies that can be used to activate and assess students' prior knowledge.
- **Student Research/Reports**
  — Learning projects that involve student research are one of the most effective ways to individualize instruction in a diverse classroom. These learning activities provide students with the opportunity to develop their research skills as they gather, process, and evaluate information.
- **Teacher Demonstration**
  — Demonstrations can arouse student interest and allow for visualization of phenomena. For instance, demonstrating discrepant events can be a powerful tool. Demonstrations can activate prior knowledge and generate discussion about learning outcomes.
- **Visual Displays**
  — When students create visual displays, they make their thinking visible. Generating diagrams, posters, or models provides students with the opportunity to represent abstract information in a more concrete form.

- **Collaborative Teamwork**
  — Instructional strategies, such as the Jigsaw or Roundtable, encourage students to learn from one another and develop teamwork skills. The use of cooperative learning activities can lead to increased understanding of content and improved thinking skills.
- **Laboratory Activities**
  — Laboratory activities, whether student- or teacher-designed, provide students with the opportunity to apply their scientific knowledge and skills related to a group of learning outcomes. Students appreciate the hands-on experience of doing science.
- **Debates**
  — Debates draw upon students' own positions on STSE issues. When carefully structured, debates can encourage students' consideration of societal concerns and the opinions of others, and improve their communication and research skills.
- **Community/Career Connection**
  — Field trips and guest speakers can provide students with the opportunity to see science applied in their community and local natural environments.