GENERAL APPENDICES

Appendix 6: Scientific Communication

One of the primary skill thrusts of Grade 12 Biology 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. For additional information about the strategies, see the following teacher resources:

- *Senior Years Science Teachers' Handbook* (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*

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

Visual communication is often more effective than a written description. Labelled diagrams may be useful for showing equipment set-ups, 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 adapted 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.

Microthemes

When provided with a case study, students interpret the events and express their ideas in a short written assignment. A microtheme may require specific thinking skills (e.g., creating an analogy, analyzing data, examining more than one point of view), and writing must be concise, detailed, and accurate. See Appendix 2.8A: Microthemes (Teacher Background) for more information.

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. 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 and 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 negotiation, 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 should 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 it 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 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 those 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 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 learning 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., chrono-) and suffixes (e.g., -logical) in scientific parlance.

Written Laboratory 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, or mini-magazines) usually treat a particular theme. Components may include

- cartoon
- collage
- editorial
- interview
- memoir
- poem
- review
- survey results

Appendix 7: 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 Grade 12 Biology 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. For additional information about the strategies, see the following teacher resources:

- *Senior Years Science Teachers' Handbook* (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*

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.

* Source: Manitoba Education and Training. *Senior 3 English Language Arts: A Foundation for Implementation.* Winnipeg, MB: Manitoba Education and Training, 1999. Section 4, p. 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:

- **Pre-reading:** Pre-reading 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 WebQuest.org <http://webquest.org/>.

NOTES

Appendix 8: 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). Further information is also provided in *Senior 3 English Language Arts: A Foundation for Implementation* (Manitoba Education and Training), abbreviated as *Senior 3 ELA* on the following pages.

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 9)

Appendix 9 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, and be structured to a particular format or free-form. It is valuable to consider how best to use journal writing in the science classroom, but experience shows that overuse defeats the purposes of the journal. For instance, if journal writing has little or no assessment/evaluation potential toward a student's grade, or does not provide a means of obtaining 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, analyses, and growth.

Laboratory Report Assessment (See Appendix 10)

The Lab Report Assessment rubric is designed for both self-assessment and teacher assessment, and includes criteria categories 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 10)

This rubric is designed with five performance criteria, and can be used for an entire class list. The emphasis is on gathering information over time through observation. The criteria categories 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.

Performance Assessment

Performance assessment may take the form of

- demonstrating a lab technique (e.g., lighting a Bunsen burner, using a micropipette, 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 in *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 proposal for a research paper.

Rubric for Assessment of Class Presentation (See Appendix 10)

This rubric is designed with four performance levels, and includes assessment criteria categories 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 10)

This rubric is designed with four performance levels, and includes criteria categories such as the following:

- Source of Information
- Information Collected
- Organization of Material
- Presentation of Material

Rubric for Assessment of Scientific Inquiry (See Appendix 10)

This rubric 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 learning activities with their students in a cooperative manner (e.g., pairings).

NOTES

Appendix 9: 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 10.
- **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" judgments from the assessors, 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.

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.

---

* Source: Manitoba Education and Training. *Senior 3 English Language Arts: A Foundation for Implementation.* Winnipeg, MB: Manitoba Education and Training, 1999. Adapted from Appendices, pp. 3 to 10.

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 Grade 12 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 that the criteria are comprehensive and consistent with learning outcomes. This collaborative process in developing rubrics

- requires students to make judgments 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 judgments 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 judgments 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.*

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.

* 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.

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 should 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 10 of this document are intended as templates, open to situational revisions.

Appendix 10: 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 of research.	❐ The information collected was relevant to the topic and was somewhat organized into a cohesive piece of research.	❐ 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 among the 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 and 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 focused, 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			

Rubric for 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 too 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 and 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 and 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 Presentation

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 was made to relate material presented to students' own experiences.	❒ Good understanding of the topic was evident. ❒ Knowledge was thorough and detailed. ❒ Attempt was made to relate 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 exceptionally 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 and record	❒ 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 of Results	❒ 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 model to data, and states *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

Appendix 11: General and Specific Learning Outcomes

General Learning Outcomes

General learning outcomes (GLOs) provide connections to the Five Foundations for Science Literacy that guide all Manitoba science curricula in all science discipline areas.

Nature of Science and Technology

As a result of their Senior Years science education, students will:

A1 Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

A2 Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

A3 Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

A4 Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

A5 Recognize that science and technology interact with and advance one another.

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

As a result of their Senior Years science education, students will:

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

B2 Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and the societal context of the time.

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

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

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

Scientific and Technological Skills and Attitudes

As a result of their Senior Years science education, students will:

C1 Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.

C2 Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

C3 Demonstrate appropriate problem-solving skills when seeking solutions to technological challenges.

C4 Demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information.

C5 Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.

C6 Employ effective communication skills and use information technology to gather and share scientific and technological ideas and data.

C7 Work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities.

C8 Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

Essential Science Knowledge

As a result of their Senior Years science education, students will:

D1 Understand essential life structures and processes pertaining to a wide variety of organisms, including humans.

D2 Understand various biotic and abiotic components of ecosystems, as well as their interaction and interdependence within ecosystems and within the biosphere as a whole.

D3 Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

D4 Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts.

D5 Understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them.

D6 Understand the composition of the universe, the interactions within it, and the implications of humankind's continued attempts to understand and explore it.

Unifying Concepts

As a result of their Senior Years science education, students will:

E1 Describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world.

E2 Describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems.

E3 Recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved.

E4 Recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them.

Cluster 0: Skills and Attitudes

Cluster 0 in Grade 12 Biology comprises various categories of specific learning outcomes that describe the skills and attitudes involved in scientific inquiry and the decision-making process for Science, Technology, Society, and the Environment (STSE) issues. From Grades 5 to 10, students develop scientific inquiry through the development of a hypothesis/prediction, the identification and treatment of variables, and the formation of conclusions. 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 initial awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning.

In Grades 11 and 12 Biology, students continue to use scientific inquiry as an important process in their science learning, but also recognize that STSE issues require a more sophisticated treatment through the decision-making process.

Teachers should select appropriate contexts to introduce and reinforce scientific inquiry, the decision-making process, and positive attitudes within the Grade 12 Biology units throughout the school year. To assist in planning and to facilitate curricular integration, many specific learning outcomes within the Skills and Attitudes cluster can link to specific learning outcomes in other subject areas.

Demonstrating Understanding

B12-0-U1 Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames…

B12-0-U2 Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concepts to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations…

Personal Perspectives/Reflection

B12-0-P1 Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2 Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3 Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4 Recognize that humans have had and continue to have an impact on the environment. (GLO: B1, B2)

B12-0-P5 Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

Scientific Inquiry/Problem Solving

B12-0-S1 Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2 Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3 Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4 Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)
Include: discrepancies in data and sources of error

B12-0-S5 Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

Decision Making

B12-0-D1 Identify and explore a current health issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2 Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3 Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4 Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5 Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-D6 Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

Information Management and Communication

B12-0-I1 Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2 Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3 Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4 Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Group Work

B12-0-G1 Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2 Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3 Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Nature of Science

B12-0-N1 Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2 Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

B12-0-N3 Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Specific Learning Outcomes

The specific learning outcomes (SLOs) identified here constitute the intended learning to be achieved by the student by the end of Grade 12 Biology. These statements clearly define what students are expected to achieve and/or be able to perform at the end of course. These SLOs, combined with the Skills and Attitudes SLOs, constitute the source upon which assessment and instructional design are based.

Part 1: Genetics

Unit 1: Understanding Biological Inheritance

B12-1-01 Outline Gregor Mendel's principles of inheritance, stating their importance to the understanding of heredity. (GLOs: A1, A2, B1, D1)

Include: principles of segregation, dominance, and independent assortment

B12-1-02 Explain what is meant by the terms *heterozygous* and *homozygous*. (GLO: D1)

B12-1-03 Distinguish between *genotype* and *phenotype*, and use these terms appropriately when discussing the outcomes of genetic crosses. (GLO: D1)

B12-1-04 Use Punnett squares to solve a variety of autosomal inheritance problems, and justify the results using appropriate terminology. (GLOs: D1, E1)

Include: monohybrid cross, dihybrid cross, testcross, P generation, F_1 generation, F_2 generation, phenotypic ratio, genotypic ratio, dominant alleles, recessive alleles, purebred, hybrid, and carrier

B12-1-05 Describe examples of and solve problems involving the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. (GLO: D1)

Examples: co-dominance, incomplete dominance, multiple alleles, lethal genes . . .

B12-1-06 Explain the basis for sex determination in humans. (GLO: D1)

Include: XX and XY chromosomes

B12-1-07 Describe examples of and solve problems involving sex-linked genes. (GLO: D1)

Examples: red-green colour-blindness, hemophilia, Duchenne muscular dystrophy . . .

B12-1-08 Use pedigree charts to illustrate the inheritance of genetically determined traits in a family tree and to determine the probability of certain offspring having particular traits. (GLOs: C8, D1)

Include: symbols and notations used

B12-1-09 Discuss ethical issues that may arise as a result of genetic testing for inherited conditions or disorders. (GLOs: A3, B1, B2, C4)

B12-1-10 Discuss the role of meiosis and sexual reproduction in producing genetic variability in offspring. (GLOs: D1, E3)

Include: crossing over and randomness

B12-1-11 Explain how chromosome mutations may arise during meiosis. (GLOs: D1, E3)

Include: nondisjunction

B12-1-12 Identify monosomy and trisomy chromosome mutations from karyotypes. (GLO: D1)

Examples: Down syndrome, Turner syndrome, Klinefelter syndrome . . .

Unit 2: Mechanisms of Inheritance

B12-2-01 Outline significant scientific contributions/discoveries that led to the current understanding of the structure and function of the DNA molecule. (GLOs: A2, A4, A5, B1, B2)

Include: timeline, individual contributions, multidisciplinary collaboration, and competitive environment

B12-2-02 Describe the structure of a DNA nucleotide. (GLOs: D1, D3)

Include: deoxyribose sugar, phosphate group, and nitrogenous bases

B12-2-03 Describe the structure of a DNA molecule. (GLOs: D1, D3)

Include: double helix, nucleotides, base pairing, and gene

B12-2-04 Describe the process of DNA replication. (GLOs: D1, D3)

Include: template, semi-conservative replication, and role of enzymes

B12-2-05 Compare DNA and RNA in terms of their structure, use, and location in the cell. (GLOs: D1, D3)

B12-2-06 Outline the steps involved in protein synthesis. (GLOs: D1, D3)

Include: mRNA, codon, amino acid, transcription, tRNA, anticodon, ribosome, and translation

B12-2-07 Relate the consequences of gene mutation to the final protein product. (GLOs: D1, D3)

Examples: point mutation in sickle-cell anemia, frameshift mutation in β-thalassemia . . .

B12-2-08 Discuss implications of gene mutation for genetic variation. (GLOs: D1, E1, E3)

Include: source of new alleles

B12-2-09 Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

B12-2-10 Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

Part 2: Biodiversity

Unit 3: Evolutionary Theory and Biodiversity

B12-3-01 Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)

Include: gene pool and genome

B12-3-02 Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

B12-3-03 Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

B12-3-04 Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

B12-3-05 Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

B12-3-06 Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

B12-3-07 Distinguish between *natural selection* and *artificial selection*. (GLOs: D1, E1, E3)

B12-3-08 Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

B12-3-09 Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

B12-3-10 Describe how populations can become reproductively isolated. (GLOs: D1, E2)

Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

B12-3-11 With the use of examples, differentiate between *convergent evolution* and *divergent evolution* (adaptive radiation). (GLOs: D1, E1)

B12-3-12 Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

Unit 4: Organizing Biodiversity

B12-4-01 Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02 Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

B12-4-03 Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

B12-4-04 Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

B12-4-05 Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06 Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

B12-4-07 Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

Unit 5: Conservation of Biodiversity

B12-5-01 Discuss a variety of reasons for maintaining biodiversity. (GLOs: B2, B5, D2)

Include: maintaining a diverse gene pool, economic value, and sustainability of an ecosystem

B12-5-02 Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

B12-5-03 Select and use appropriate tools or procedures to determine and monitor biodiversity in an area. (GLOs: C1, D2, C7)

Examples: field guides, dichotomous keys, quadrats, transects, mark and recapture . . .

B12-5-04 Investigate an issue related to the conservation of biodiversity. (GLOs: C4, C6, C8, D2, E2)

Examples: heritage seeds, water quality in Lake Winnipeg, land-use designations, hydroelectric development . . .