Contents

Introduction

What is Smarter Science?

Smarter Science is a framework for teaching and learning science in grades 1–12 and for developing the skills of inquiry, creativity, and innovation in a meaningful and engaging manner. Students engaged in Smarter Science–based activities are actively investigating and problem solving, enabled by a teacher who helps them address challenges relevant to their world. As they learn to think and act like scientists, students become increasingly independent and self-confident learners.

Originally developed in the Thames Valley District School Board, Smarter Science was piloted in 50 schools in Ontario between 2006 and 2010. School boards across the province soon began to recognize the value of the framework, as did Youth Science Canada. Smarter Science is now part of Youth Science Canada's program for engaging youth in science and providing a curricular connection to project-based science and science fairs. Youth Science Canada is collaborating with members of the education community, including school boards, teachers, parents, and ministries of education, to train teachers to teach the processes of inquiry and technological problem solving.

A key feature of Smarter Science is its open-source nature. All resources developed by cooperating school boards and contributing teachers can be accessed online, at no cost, through www.smarterscience.ca and www.educasciences.ca, and resources may be freely reproduced and distributed.

> As they learn to think and act like scientists, students become increasingly independent and self-confident learners.

Why Smarter Science?

Smarter Science evolved from a need to make the Ontario elementary science and technology curriculum and the secondary science curriculum come alive for students, with classroom activities that reflect the investigative, creative, and social nature of science. Teachers—particularly elementary teachers, who are often less comfortable with their own knowledge of science—need an effective framework for teaching science that actively engages students, incorporates literacy and numeracy learning, and develops thinking skills, problem-solving skills, and independent learners.

Smarter Science is a framework, not a program; it is a means for teaching students how to *do* science, but does not tell you what to teach. Smarter Science, when introduced appropriately, results in learners that are engaged in the process of science and more than willing to create, innovate, and explore the science curriculum.

Thinking Like a Scientist

What do scientists do?

- They ask questions about, and make systematic observations, of natural phenomena.
- They record observations and conduct experiments where possible.
- They use the data they collect to develop models that explain the phenomena.
- They test their models repeatedly, and discard, refine, or confirm them.

Smarter Science aims to teach students the process scientists use to learn about the world.

smarter science / éduca sciences

INITIATE & PLAN
- Identifying a problem or need through curious observation
- Defining testable questions, researching and considering possible answers and solutions
- Revisiting observations and predictions to improve testable question

Observing
Using the 5 senses to find out about objects and events: their characteristics, properties, differences, similarities, and changes. Observation can be made directly with the senses or indirectly through the use of simple or complex instruments.

Questioning
A strategy to make meaning or wonder about uncertainties.

Searching
Locating and using several sources, developing self-reliance in acquiring library and Internet skills.

Interviewing
Asking, interviewing, and corresponding to gain primary information.

Inferring
Using logic to draw conclusions from the results of investigating/problem-solving.

Predicting
Predictions are not random guesses but speculations of what may occur in the future based on prior knowledge, observations, and reasoning.

Hypothesizing
Making educated guesses or predictions based on evidence that must be tested through experimentation to establish credibility. Hypotheses guide investigations from which further predictions can be made. Hypotheses generally follow an "If..., then...." statement format.

Modeling
Constructing physical/concrete or abstract representations of ideas, objects or events to clarify explanations or demonstrate relationships. Models are used to reinforce concepts, demonstrate learning, and/or illustrate phenomena which cannot be directly observed.

Investigating
Gathering background information, formulating problems/hypotheses.

ENGAGE

PERFORM & RECORD
- Developing and safely carrying out an investigation
- Observing, collecting, and recording results

Using Instruments
Knowing the instrument's parts, how it works, how to adjust it, its proper use for a given task, its limitations; knowing how to store it and transport it safely.

Calibrating
Checking, adjusting, or determining by comparison with a standard (e.g., calibrating a thermometer, balance, timer or other instrument).

Measuring
Assigning numbers to observations, e.g., metric units, time, student-generated units, using appropriate measuring devices and techniques.

Recording
Noting, documenting, tabulating, charting; working systematically, working regularly.

Planning
Working systematically, regularly organizing for future, seeing possible results.

Designing
The overall plan or strategy by which hypotheses/research questions and technological problems are answered (with or without innovation).

Gathering Data
Collecting evidence through measurements, facts, figures, pieces of information, statistics (either historical or derived by calculation), experimentation, surveys, etc.

Demonstrating
Setting up apparatus, making it work, describing parts and functions, illustrating scientific principles.

Constructing
Putting together component parts; to build or erect.

Inventing
Designing something useful, for the first time, through the use of the imagination, ingenious thinking and/or experimentation.

Experimenting
Carrying out a designed investigation to test a hypothesis or answer a question.

EXPLORE

ANALYZE & INTERPRET
- Reviewing results carefully by examining data and identifying patterns
- Deciding what the results mean
- Evaluating and refining solutions

Comparing
Looking for similarities.

Contrasting
Looking for differences.

Classifying
Putting things into groups and subgroups, identifying categories, deciding between alternatives.

Outlining
Employing major headings and subheadings; using sequential, logical organization.

Graphing
Visually representing data.

Analyzing
Seeing implications and relationships, discerning causes and effects, locating new problems.

Evaluating
Recognizing good and poor features; judging and assessing.

Reviewing
Picking out important items, memorizing, associating.

EXPLAIN

COMMUNICATE
- Explaining procedures and results through writing, speaking, visual or electronic means
- Reflecting on the process and checking with peers

Discussing
Engaging in oral, written, or any other appropriate form of communication with others.

Explaining
Clearly describing, clarifying main points and focusing on the "why" and/or "how" of the issue, concept or idea.

Reporting
Organizing and presenting information in a written or oral format.

Writing
Conveying information (e.g., questions, observations, experimental report) by graphical means.

Reflecting
The activity of either an individual or group that involves analyzing, judging the importance of, and making connections to the learning experience.

Teaching
Making meaning of concepts or processes by organizing them into key facts and ideas and clearly conveying them to others.

EXTEND

BEGINNING · EXPLORING · EMERGING · COMPETENT · PROFICIENT

A S S E S S   &   E V A L U A T E

Adapted from research by Trowbridge, Bybee and Powell 2000

Ontario

www.smarterscience.ca

Youth Science Canada
Sciences jeunesse Canada

The Smarter Science Framework

The poster at left summarizes the Smarter Science framework. The process skills of science are divided into four columns, each corresponding to a stage in the problem-solving process. The learning continuum identifies how students will progress as they learn each process skill. The skills are also correlated to the 5Es Instructional Model (see p. 5).

Process Skills

At the heart of Smarter Science are 34 process skills—the skills necessary to do science (Bybee, Powell, and Trowbridge, 2008). These include everything from observing and interviewing to calibrating, constructing, and reporting. The definition of each skill has been synthesized from definitions in multiple sources, both in print and online.

Within each column, the most basic process skills are near the top and more advanced skills are near the bottom. But do not confuse "advanced" skills with "important" skills. For example, Observing and Questioning, though basic, are the most important skills for students to learn.

Each skill must be taught explicitly so that students have a common understanding. Students must also have an opportunity to practise and apply each skill. This guide examines the process skills in detail.

Four Stages of Problem Solving

Each column of skills corresponds to a stage in the process of solving a problem:

◆ Become aware of a problem and formulate a testable question that can be investigated
◆ Conduct the investigation and collect information
◆ Analyze the information and interpret the results
◆ Communicate the results to others

In any scientific inquiry, students will move through each stage of the problem-solving process, using whichever skills are applicable.

INITIATE & PLAN

The process skills in this stage of the problem-solving process enable students to develop a testable question that they can investigate.

◆ Identifying a problem or need through curious observation
◆ Defining testable questions, researching and considering possible answers and solutions
◆ Revisiting observations and predictions to improve testable question

The most important of all scientific skills—perhaps the most important skill across all disciplines—is the ability to observe, and observe well. The scientist must be able to observe and record everything, and every student must learn to differentiate between an observation and an assumption. Quite often, students observe and derive an assumption from the observation. For example, some observations of a ping-pong ball may be that it is spherical, white, and a hard substance. When students say that it is made of plastic they are not observing; they are incorporating prior knowledge into what they think is an observation. Typically, using only the five senses, students are limited to the observation that the ping-pong ball is made of "a hard substance."

Students should complete their planning for an investigation before they move to the next stage, Perform & Record. You may also want to assess your students' plans before they proceed, especially when students are new to the Smarter Science framework. Check whether students have taken safety precautions, whether the equipment and resources requested are available, and whether the plan is "doable."

PERFORM & RECORD

◆ Developing and safely carrying out an investigation

◆ Observing, collecting, and recording results

This is the hands-on stage of problem solving, where students put their question to the test.

Students must think about and develop ways to record the data that results from their investigation (e.g., tables, T-charts, checklists). Students working in groups must also assign roles to each other (e.g., you pour and I'll measure).

Scientific problem solving is answering questions about what we know about the world (e.g., What factors affect plant growth?). Technological problem solving is solving a practical problem (e.g., What's the most efficient way for farmers to apply fertilizer to their fields?). Most of the skills in this column apply to both scientific problem solving and technological problem solving. The exceptions are Constructing and Inventing, which lend themselves more to technological problem solving, and Experimenting, which applies more to scientific problem solving.

ANALYZE & INTERPRET

◆ Reviewing results carefully by examining data and identifying patterns

◆ Deciding what the results mean

◆ Evaluating and refining solutions

Once they have carried out their investigation, students must analyze and evaluate their data and determine what the results mean.

The process skills in this stage of the problem-solving process are most directly related to numeracy. For example, in order to analyze and evaluate the data, students may have to graph or otherwise illustrate relationships that become apparent.

COMMUNICATE

◆ Explaining procedures and results through writing, speaking, visual or electronic means

◆ Reflecting on the process and checking with peers

It is very important for students to communicate their results and their analyses to others. The continuum of process skills in this final stage of the problem-solving process suggests a gradual expansion of the sphere of communication. Students begin by Discussing and Explaining the investigation to peers but can then create a product, such as an oral report, essay, or video, to present their investigation and its results to a variety of audiences (Reporting).

Reflecting is a key process skill that must be part of all Smarter Science investigations. Students must be able to examine what they have done, suggest changes or improvements, and establish priorities for future investigations. Formal reflection occurs in the Communicate stage, but students should be encouraged to reflect on their actions throughout the inquiry process.

Learning Continuum

The learning continuum shows the levels of proficiency that students should move through as they learn and practise each skill: everyone starts as a beginner, gains skill and

experience (explore, emerge), becomes competent, and eventually becomes an expert. The milestones "beginning" through "proficient" are not specific to grade or age. For example, a student in grade 3 may be proficient at Teaching (e.g., explaining to others how plants grow) and a student in grade 12 may be a beginner at Using Instruments (e.g., gel electrophoresis). It is up to you, the teacher, to determine the ability level of your students, consolidate their prior knowledge and skills, and help them to progress along the learning continuum.

The 5E Instructional Model

Smarter Science process skills are correlated to the 5E Instructional Model of inquiry-based science created and popularized by Roger Bybee of Biological Sciences Curriculum Study (BSCS) in Colorado. The key ingredient in the 5E model is that students must be engaged and allowed to explore *before* the teacher conveys the content. In both Smarter Science and the 5E model, teachers assess student progress and provide feedback continuously, throughout the inquiry process. Once your students are familiar with process skills and the stages of problem solving, you can evaluate at the end of an investigation or inquiry.

> Students must be engaged and allowed to explore *before* the teacher conveys the content.

Smarter Science Goes Beyond Science

Process Skills Are Transferable

If you examine all of the process skills, you will see that none are specific only to science. Once you understand the Smarter Science framework, you will find it easy to apply to other subjects.

Smarter Science Develops Literacy and Numeracy

The Smarter Science framework also incorporates numeracy and literacy skills. In order to design an investigation, students must record their observations and questions. As students' design abilities become more sophisticated, they will be reading additional background information in order to plan their investigations. Recording data throughout an investigation requires skills in technical writing. Numeracy skills like data gathering, graphing, and data analysis are required to make sense of the results of the investigation. Literacy skills figure prominently when students communicate the results of their investigation, whether orally or in writing.

Smarter Science Incorporates Bloom's Taxonomy

Bloom's taxonomy, which categorizes thinking skills, is built into the arrangement of process skills. If you imagine a diagonal line from the top left of the poster to the bottom right, you can see the progression from lower- to higher-order thinking skills.

▍About This Guide

On the following pages, you will learn more about each process skill, including what students and teachers engaged in the skill should and should not be doing. A brief glossary defines some of the teaching techniques and strategies mentioned throughout. For resources (e.g., graphic organizers) to help implement Smarter Science in your classroom, visit www.smarterscience.ca.

problem-solving stage

process skill

introduction

definition

guidlines for students

guidlines for teachers

objectives

INITIATE & PLAN

Observing

Observation is a fundamental science process skill that is often overlooked. However, like all skills, it can be developed with practice and feedback. It is student observations that lead to questioning and the process of inquiry. Observing is the key to understanding objects and phenomena in the world and interactions between objects or phenomena. It can also be a "hook" for further inquiry—looking closely can generate new questions, which lead to further investigations.

Definition:
Using the 5 senses to find out about objects and events: their characteristics, properties, differences, similarities and changes. Observation can be made directly with the senses or indirectly through the use of simple or complex instruments.

STUDENTS

Observing is...
✔ using all five senses, as appropriate, to thoroughly understand an object's natural state
✔ detecting details in natural phenomena that go beyond that of the casual observer
✔ building understanding by connecting to past experiences

✘ **not** limited to sight or touch
✘ **not** using simple, overused words with little descriptive value (e.g. pretty, little, nice)
✘ **not** attributing cause to the observations
✘ **not** the same for every student—different students will make different observations

TEACHERS

Observing is...
✔ prompting students to use all five senses
✔ encouraging students to use expansive, descriptive vocabulary, including scientific terms
✔ encouraging students to make connections to past experiences (e.g., what does this remind you of?)
✔ providing multiple opportunities to practise
✔ giving students problems that require them to decide what evidence (observations) are relevant, and to interpret the evidence

✘ **not** telling students to notice specific aspects of an object or phenomenon, or explaining observations (e.g., don't tell students who see perfect spheres when examining slides under a microscope that these are trapped air bubbles)
✘ **not** expecting every student to notice the same set of details

WHAT THIS SKILL SHOULD LEAD TO

Systematic observation develops an enhanced descriptive vocabulary that becomes important as students practise other science skills, such as writing and reviewing. As students become better observers, they will become better able to detect patterns, classify information, predict events, and make inferences. Math skills will also improve, and students will have opportunities to integrate skills from the arts, including visual art, drama, and dance. Finally, observing leads to discussions of the role of bias when observations are interpreted by different observers.

Initiate & Plan

INITIATE
& PLAN

Observing

Questioning

Searching

Interviewing

Inferring

Predicting

Hypothesizing

Modeling

Investigating

WHAT IT IS

◆ **Identifying a problem or need through curious observation**
◆ **Defining testable questions, researching and considering possible answers and solutions**
◆ **Revisiting observations and predictions to improve testable question**

PROCESS SKILLS

Observing
Using the 5 senses to find out about objects and events: their characteristics, properties, differences, similarities, and changes. Observation can be made directly with the senses or indirectly through the use of simple or complex instruments.

Questioning
A strategy to make meaning or wonder about uncertainties.

Searching
Locating and using several sources, developing self-reliance in acquiring library and Internet skills.

Interviewing
Asking, interviewing, and corresponding to gain primary information.

Inferring
Using logic to draw conclusions from the results of investigating/problem-solving.

Predicting
Predictions are not random guesses but speculations of what may occur in the future based on prior knowledge, observations, and reasoning.

Hypothesizing
Making educated guesses or predictions based on evidence that must be tested through experimentation to establish credibility. Hypotheses guide investigations from which further predictions can be made. Hypotheses generally follow an "If..., then...." statement format.

Modeling
Constructing physical/concrete or abstract representations of ideas, objects or events to clarify explanations or demonstrate relationships. Models are used to reinforce concepts, demonstrate learning, and/or illustrate phenomena which cannot be directly observed.

Investigating
Gathering background information, formulating problems/hypotheses.

Observing

Definition:

Using the 5 senses to find out about objects and events: their characteristics, properties, differences, similarities and changes. Observation can be made directly with the senses or indirectly through the use of simple or complex instruments.

Observation is a fundamental science process skill that is often overlooked. However, like all skills, it can be developed with practice and feedback. It is student observations that lead to questioning and the process of inquiry. Observing is the key to understanding objects and phenomena in the world and interactions between objects or phenomena. It can also be a "hook" for further inquiry—looking closely can generate new questions, which lead to further investigations.

STUDENTS

Observing is...

✔ using all five senses, as appropriate, to thoroughly understand an object's natural state

✔ detecting details in natural phenomena that go beyond that of the casual observer

✔ building understanding by connecting to past experiences

✘ **not** limited to sight or touch

✘ **not** using simple, overused words with little descriptive value (e.g. pretty, little, nice)

✘ **not** attributing cause to the observations

✘ **not** the same for every student—different students will make different observations

TEACHERS

Observing is...

✔ prompting students to use all five senses

✔ encouraging students to use expansive, descriptive vocabulary, including scientific terms

✔ encouraging students to make connections to past experiences (e.g., what does this remind you of?)

✔ providing multiple opportunities to practise

✔ giving students problems that require them to decide what evidence (observations) are relevant, and to interpret the evidence

✘ **not** telling students to notice specific aspects of an object or phenomenon, or explaining observations (e.g., don't tell students who see perfect spheres when examining slides under a microscope that these are trapped air bubbles)

✘ **not** expecting every student to notice the same set of details

WHAT THIS SKILL SHOULD LEAD TO

Systematic observation develops an enhanced descriptive vocabulary that becomes important as students practise other science skills, such as writing and reviewing. As students become better observers, they will become better able to detect patterns, classify information, predict events, and make inferences. Math skills will also improve, and students will have opportunities to integrate skills from the arts, including visual art, drama, and dance. Finally, observing leads to discussions of the role of bias when observations are interpreted by different observers.

Questioning

Definition:
A strategy to make meaning or wonder about uncertainties.

Questioning—asking who, what, when, where, why, and how—leads to student inquiry and investigation. It is the underlying basis for Smarter Science and is a fundamental part of the inquiry process. Questioning arouses curiosity, promotes idea development, stimulates discussion, clarifies concepts, emphasizes key ideas, motivates students, encourages higher-order thinking, and activates prior knowledge. Teaching effective questioning skills leads to increased student engagement and ownership.

STUDENTS

Questioning is...

✔ students leading the discussion and subsequent inquiry

✔ an interactive activity during which students record their curiosity

✔ activities where students develop higher-order thinking and engage in high level discussion

✔ asking who, what, when, where, why, and how—questions that lead to true discussion and inquiry

✔ a dynamic process whereby questions lead to new questions and new ideas for investigations

✘ **not** teachers leading the discussion

✘ **not** asking just 'what' questions (which lead to one-word answers)

TEACHERS

Questioning is...

✔ encouraging various types of questions (e.g., scaffolding questions using Bloom's taxonomy: knowledge, comprehension, application, analysis, synthesis, evaluation, and creating)

✔ using teaching supports to develop higher-order thinking (e.g., Q-chart activity)

✔ prompting students to extend, clarify, and justify their questions, to extend learning and engage more students

✔ prompting students to reformulate their questions so that they are "testable"

✔ establishing a classroom of inquiry where everyone's ideas are honoured

✔ allowing wait time for students to think

✘ **not** asking the first student with their hand up

✘ **not** investigating only teacher-generated questions

✘ **not** led by the teacher

✘ **not** Yes or No questions

✘ **not** using rhetorical questions (these mislead and confuse students)

WHAT THIS SKILL SHOULD LEAD TO

Questioning leads to a deeper understanding of the scientific concept being investigated. Rich questions lead to rich inquiries, which in turn generate more questions. Questioning also leads to participation and engagement in literacy activities—reading, researching, writing, speaking, and presenting.

Smarter Science: Introducing the Framework

Searching

Definition:
Locating and using several sources, developing self-reliance in acquiring library and Internet skills.

In a world of information overload, the ability to locate information and assess its quality is an important step in developing critical literacy in science. Students should actively mine information rather than passively accepting it. Searching for information about a question is an important part of the inquiry process. Some questions can be answered through hands-on investigations, while other questions are best answered through searching for information.

STUDENTS

Searching is...

✔ locating their own sources of information based on their own questions

✔ re-framing their current understanding in light of new evidence

✔ evaluating the reliability of sources of information

✔ identifying potential sources of error and/or bias

✔ developing and using criteria to establish relevance, accuracy, and reliability of information

✔ discussing research with peers and teachers to gain additional perspective and construct new meaning

✔ developing and using strategies to collect, organize, and communicate relevant research

✔ developing and using strategies to interpret scientific vocabulary

✘ **not** expecting immediate answers to questions

✘ **not** copying and pasting information directly from resources

✘ **not** using a single source for information

TEACHERS

Searching is...

✔ giving students sufficient time and resources for research

✔ giving students guidance and activities to develop research skills

✔ developing criteria for reliability

✔ giving students opportunities to discuss and question their research

✔ guiding the development of strategies to interpret scientific text

✘ **not** providing the "correct answers"

✘ **not** providing a limited, teacher-supplied list of approved resources

WHAT THIS SKILL SHOULD LEAD TO

➔ critical literacy skills that enable assessment of information for accuracy, reliability, and relevance

➔ strategies for interpreting and understanding scientific text

➔ cooperative learning (through discussion of research with peers)

Interviewing

Definition:
Asking, interviewing, and corresponding to gain primary information.

Interviewing develops critical thinking skills as students generate appropriate and pertinent questions. This research technique is often a source of primary information. Students learn to recognize and discover bias or irrelevant information so that these do not influence their decisions or concluding thoughts.

STUDENTS

Interviewing is...

✔ a structured conversation

✔ using a series of predetermined questions based on the topic and fitting the area of expertise of the interviewee

✔ providing the interviewee with a copy of the questions ahead of time

✔ in multiple interviews, using the same interview format and questions to allow for valid interpretation

✔ taking notes or recording the exchange for future reference

✔ being courteous, polite, and respectful

✘ **not** asking personal questions or questions that are irrelevant to the topic

✘ **not** surprising the interviewee with unexpected questions that require details and/or statistics the interviewee may not have on hand

✘ **not** asking questions abruptly or impolitely

TEACHERS

Interviewing is...

✔ guiding students to ask questions at various levels (see Bloom's taxonomy)

✔ giving students time to practise interviewing skills

✔ reviewing students' questions to ensure that they are concise and related to the topic

✔ ensuring that the interviewee has the potential to add value to the research

✔ encouraging students to identify possible bias on both sides of the interview

✘ **not** giving students a list of questions

✘ **not** supporting random, repetitive, or disconnected interviews

WHAT THIS SKILL SHOULD LEAD TO

➔ the development of probing, higher-level questions

➔ the knowledge that primary data is an important source of information and adds to the inquiry process

➔ opportunities to interpret responses and evaluate for bias

Definition:
Using logic to draw conclusions from the results of investigating/problem-solving.

Inferring is using logic and reason to develop explanations from evidence. It is thinking beyond the information available and making links with unstated ideas or information. Inferring requires students to "read between the lines." Students may often use prior knowledge to infer purpose, intent, or cause and effect.

STUDENTS

Inferring is...

✔ deducing information from incomplete evidence using reasoning or logic. The information does not need to be factual or correct. (For example, "The grass is wet in the morning, so I infer that it rained overnight." This is a valid inference, but not necessarily a correct one—the wet grass could be from morning dew or a sprinkler system.)

✔ clarifying observations as evidence

✔ making a connection between what is known and what is unknown

✔ creating a tentative understanding of the situation without knowing or being given the "answer"

✘ **not** predicting

✘ **not** guessing

✘ **not** based on another's perspective

✘ **not** waiting to be told the answer

✘ **not** easy!

TEACHERS

Inferring is...

✔ guiding students to make logical connections from available evidence

✔ encouraging students to consider alternative inferences

✔ scaffolded and deliberate

✔ using a modified K-W-L chart to show the process of making an inference: replace "What I know," What I want to learn," and "What I learned" with "What I know," "What I observed," and "What I infer"

✘ **not** quick and easy

✘ **not** a worksheet and answer key

✘ **not** every student making the same inference

✘ **not** teacher-directed

WHAT THIS SKILL SHOULD LEAD TO

➜ improved observation and deduction skills

➜ the ability to identify and analyze available evidence

➜ improved literacy skills as inferencing skills are applied to make meaning of written texts

Predicting

Definition:

Predictions are not random guesses but speculations of what may occur in the future based on prior knowledge, observations, and reasoning.

Predicting is one of the foundational skills in the inquiry process. A prediction or forecast is a statement about the way things will happen in the future. A testable prediction is based on prior experience, physical evidence, and understanding.

Students often lack the experience necessary to make predictions. Teachers may need to provide prior experiential opportunities on which students can base their predictions. Asking students to predict without prior experience results in guesswork.

For the purposes of inquiry, predictions must be testable, though in some fields this is not always possible (e.g., paleontology, astronomy, taxonomy or classification).

STUDENTS

Predicting is...

✔ a clear statement or diagram(s) that explains what will happen in a future event, such as a demonstration, activity, or exploration. Predictions can take the form of "If…, then…" statements.

✘ **not** making guesses without prior experience, physical evidence, and understanding

✘ **not** predictions made on unrelated topic(s)

✘ **not** an "If..., then… because…" statement, since predictions do not include a rationale

TEACHERS

Predicting is...

✔ allowing for brainstorming about a given observation/statement

✔ guiding students to speculate on what might happen

✔ providing prompts to encourage students to predict (e.g., I predict that… or I think that…)

✘ **never** a standalone component of inquiry. A prediction accompanied by a tentative explanation or rationale becomes a hypothesis. (See 'Hypothesizing.')

WHAT THIS SKILL SHOULD LEAD TO

Predictions are the foundation for formulating testable questions, and are required for any controlled experiment.

Hypothesizing

Definition:

Making educated guesses or predictions based on evidence that must be tested through experimentation to establish credibility. Hypotheses guide investigations from which further predictions can be made. Hypotheses generally follow an "If..., then...." statement format.

Hypotheses are suggested explanations of phenomena based on evidence at hand. Hypothesizing requires students to provide a rationale or reasons for their prediction. This is an opportunity for students to combine background research and prior knowledge to support their thinking.

Hypotheses arise from previous observations, models, or theories. They express a cause and effect relationship (identify independent and dependent variables). A hypothesis can be used as a starting point for further investigation.

STUDENTS

Hypothesizing is...

✔ detailing the support for a prediction

✔ using the word "because" (e.g., The penny will float because….)

✔ usually done prior to conducting investigations

✘ **not** a judgment or personal opinion

✘ **not** a random guess of what is going to happen

✘ **not** a vague statement or prediction (e.g., The penny will float in the liquid.)

TEACHERS

Hypothesizing is...

✔ emphasizing the link between research, models, and theories to make reasoned predictions

✔ a creative process where students develop an understanding of how the world works

✔ guiding students to independently develop their own logic and reasoning

✘ **not** written after students have finished their inquiries to ensure their hypothesis is correct

✘ **not** proven in a scientific inquiry—it is either supported or not supported. An inquiry that supports a hypothesis increases confidence in the hypothesis and the underlying theory that generated it. A hypothesis that is not supported by the data needs to be revised, modified, or discarded.

✘ **never** "right" or "wrong." A scientific inquiry can be very successful even if the hypothesis is not confirmed.

WHAT THIS SKILL SHOULD LEAD TO

Hypotheses help set the methodology of a scientific inquiry by providing a proposed relationship between the variables being tested. Hypotheses also need to be addressed when reporting results and conclusions. Developing this skill will help students connect their inquiries with past research and theories, and possibly lead to further inquiry.

Modeling

Definition:
Constructing physical/concrete or abstract representations of ideas, objects or events to clarify explanations or demonstrate relationships. Models are used to reinforce concepts, demonstrate learning, and/or illustrate phenomena which cannot be directly observed.

Models are simplified depictions of the real world. Modeling increases understanding through the development of physical, conceptual, or computer representations of natural phenomena. It also fosters higher-order thinking skills. Models can be used to convey abstract concepts in a tangible form (e.g., atomic models). Models can also be used to perform an experiment that cannot be done in the real world (e.g., wind tunnels, wave tanks, weather modeling programs). Models help their makers to develop ideas and/or present understanding.

STUDENTS

Modeling is...

✔ making physical/concrete representations of a concept, object, or event using different formats (e.g., graphic/computer simulation, 3D model)

✔ a way to visualize something that may not be directly observed

✔ a way of predicting future events based on present circumstances (e.g., flood plain table)

✔ a way to reinforce what is already known about a concept

✔ developed through a planning process

✗ **not** memorizing labeled diagrams from the teacher or textbook

✗ **not** using a kit (e.g., Lego or K'nex) with predetermined instructions

TEACHERS

Modeling is...

✔ a way to reach visual and kinesthetic learners

✗ **not** teacher-directed

✗ **not** published instructions or procedures from outside sources

WHAT THIS SKILL SHOULD LEAD TO

Modeling increases the ability to

➔ understand an abstract idea or a phenomenon which may not be directly observed;

➔ determine relationships between ideas, objects, or events; and

➔ clarify explanations.

Modeling also leads to further inquiry about relationships between ideas, objects, or events.

Investigating

Definition:
Gathering background information, formulating problems / hypotheses.

Investigating is doing background research. When conducting an inquiry, it is important to learn more about the topic of study. A clearly defined hypothesis must incorporate background information from various sources. Through investigation, students survey the experiences of others and learn about possible methods and/or solutions to pursue.

STUDENTS

Investigating is...

✔ background research done to further the inquiry process

✔ gathering information from a variety of sources (e.g., interviews, printed texts, online sources)

✘ **not** using one website (e.g., Wikipedia) as a single source of information

✘ **not** using the Internet to find out what is supposed to happen in a lab and why

TEACHERS

Investigating is...

✔ giving students opportunities to complete relevant research

✔ ensuring that students have a clearly defined testable question or problem statement to guide their information search

✔ teaching students appropriate search strategies (see 'Searching')

✘ **not** taking students to a computer lab or library for unstructured research time

WHAT THIS SKILL SHOULD LEAD TO

Doing background research helps students put concepts in context. It also leads to richer questions or problems that stimulate further inquiry, and more success in applying skills, concepts, and techniques. Investigation skills can be used to conduct research in any subject area.

Perform & Record

Process Navigation
PERFORM & RECORD
Using Instruments
Calibrating
Measuring
Recording
Planning
Designing
Gathering Data
Demonstrating
Constructing
Inventing
Experimenting

WHAT IT IS

◆ **Developing and safely carrying out an investigation**
◆ **Observing, collecting, and recording results**

PROCESS SKILLS

Using Instruments
Knowing the instrument's parts, how it works, how to adjust it, its proper use for a given task, its limitations; knowing how to store it and transport it safely.

Calibrating
Checking, adjusting, or determining by comparison with a standard (e.g., calibrating a thermometer, balance, timer or other instrument).

Measuring
Assigning numbers to observations, e.g., metric units, time, student-generated units, using appropriate measuring devices and techniques.

Recording
Noting, documenting, tabulating, charting; working systematically, working regularly.

Planning
Working systematically, regularly organizing for future, seeing possible results.

Designing
The overall plan or strategy by which hypotheses / research questions and technological problems are answered (with or without innovation).

Gathering Data
Collecting evidence through measurements, facts, figures, pieces of information, statistics (either historical or derived by calculation), experimentation, surveys, etc.

Demonstrating
Setting up apparatus, making it work, describing parts and functions, illustrating scientific principles.

Constructing
Putting together component parts; to build or erect.

Inventing
Designing something useful, for the first time, through the use of the imagination, ingenious thinking and / or experimentation.

Experimenting
Carrying out a designed investigation to test a hypothesis or answer a question.

Using Instruments

Definition:
Knowing the instrument's parts, how it works, how to adjust it, its proper use for a given task, its limitations; knowing how to store it and transport it safely.

Students collecting primary data need to be aware of what kinds of data can be collected by various instruments. Modern science needs to be precise, and the accuracy and reliability of data often depends on choosing and correctly using the right instruments. Students should be given the chance to properly and safely operate several types of equipment to learn their uses and limitations. Using Instruments is closely related to Calibrating, Recording, and Gathering Data.

STUDENTS

Using instruments is...

✔ safely, actively, and regularly using instruments and equipment in their inquiries

✔ selecting, operating, and maintaining scientific instruments

✔ communicating why they are using one piece of equipment over another

✔ taking responsibility for safely using scientific instruments and equipment

✘ **not** using only "advanced" pieces of equipment. Basic instruments (e.g., thermometers, graduated cylinders, and scales) can be used to do deep and meaningful science. In fact, students can learn much from designing, building, and calibrating their own instruments (e.g., make hydrometers from pencils and modeling clay).

✘ **not** reading about equipment and drawing and labeling parts

✘ **not** using instruments and equipment without a purpose

TEACHERS

Using instruments is...

✔ allowing students to choose the instruments and equipment they need to use within a given context

✔ promoting the importance of using instruments through assessment and evaluation, and making the criteria for assessment and evaluation available to students

✔ creating a culture of safe practice and responsibility in their science classes

✘ **not** exposing students to instruments or lab equipment without giving students a chance to regularly use them and to explore their benefits and limitations

✘ **not** doing things *for* students (e.g., setting up, using, and putting away instruments)

✘ **not** discussing and/or demonstrating the importance of instruments without letting students actually use them

✘ **not** limiting the use of equipment to prescriptive situations. Students must be allowed to select the most appropriate instruments and equipment for a given task.

WHAT THIS SKILL SHOULD LEAD TO

Students will become competent users of scientific instruments. They will understand the important of collecting data using instruments safely and will be able to choose appropriate instruments to use in novel situations.

Calibrating

Definition:

Checking, adjusting, or determining by comparison with a standard (e.g., calibrating a thermometer, balance, timer or other instrument).

Calibrating is checking and adjusting instruments to ensure accuracy and validity in an investigation. The process of calibrating an instrument is usually done by comparison with a standard (e.g., calibrating a thermometer, balance, timer or other instrument). Calibrating permits students to compare their results with confidence since they are sharing the same frame of reference.

STUDENTS

Calibrating is...

✔ developing standards for calibrating. Students can set these but they need to be justified by logic

✔ setting standards, units of measure, and quantities to ensure the experiment has accurate, reproducible results

✔ the ability to repeat an experiment and get similar results

✘ **not** calibrating without comparison to a known standard.

✘ **not** using an instrument before checking that it is working correctly

TEACHERS

Calibrating is...

✔ encouraging students to choose and calibrate measurement tools. This may also include creating measurement tools when necessary.

✔ setting some standards for calibration but allowing students to decide what parts of the experiment need precise measurements and standards for comparison

✔ giving students the freedom to calibrate their instruments or set standards for the experiment

✔ demonstrating to students various ways to record their data with the instruments chosen

✘ **not** allowing experiments to proceed without instrument calibration

✘ **not** choosing experiments where there is no calibrating needed

WHAT THIS SKILL SHOULD LEAD TO

In acquiring good calibration skills, students develop math skills and sharp hand-eye coordination. They also acquire the ability to analyze and interpret data and other information in order to complete calibration procedures.

Measuring

Definition:

Assigning numbers to observations, e.g., metric units, time, student-generated units, using appropriate measuring devices and techniques.

Measuring in experimentation gives quantitative observations. Scientists use a large variety of measuring tools, and a common system of measurement to allow interpretation of scientific measurements/results in any language or culture. The accuracy in measuring affects the validity of any experiment. Students must know how to use measuring tools, choose appropriate units of measurement, and measure with accuracy.

STUDENTS

Measuring is...

✔ choosing the appropriate measuring device; for example:
- ◆ when measuring the temperature in a room, using a thermometer designed for temperatures within a narrow range, 0–45°C
- ◆ when measuring 20 mL of liquid, using a graduated cylinder that goes up to 25 mL

✔ choosing appropriate units of measurement (e.g., centimetres for the dimensions of a book, millimetres for the dimensions of dice, metres for the dimensions of a room)

✔ using instruments that have been calibrated (see 'Calibrating')

✔ understanding and using standardized techniques (e.g., bending down to correctly read the meniscus at eye level when measuring fluid levels)

✔ using consistent measuring techniques and taking repeated readings

✘ **not** using other students' data

✘ **not** altering data to conform to expected results

✘ **not** discarding data without documenting the reasons (e.g., a fly landed on my balance during massing)

✘ **not** using a measuring tool that has inappropriately large or small increments of measure for a given object (e.g., using a metre stick to measure the length of a mealworm, using a 100 mL beaker with 25 mL markings to measure 20 mL)

TEACHERS

Measuring is...

✔ reminding students to calibrate measuring tools before use

✔ allowing students to choose the appropriate unit of measurement and measuring tool for a task (e.g., use a 10 mL graduated cylinder to measure 8 mL of liquid)

✔ teaching students to make careful and accurate readings of measurements; modeling standardized techniques

WHAT THIS SKILL SHOULD LEAD TO

Careful and accurate measurement using appropriate instruments produces good quantitative data that supports students' qualitative observations and allows for meaningful learning in context. Making measurements also allows students to appreciate calibration and become more familiar with the various scientific measuring tools.

Recording

Definition:
Noting, documenting, tabulating, charting; working systematically, working regularly.

Recording is collecting and organizing the data from an experiment. The record of an experiment can include video, measurements, descriptions, drawings, tables, charts, graphic organizers, anecdotes, and more. A permanent record of an event or experience captures it in time and makes possible further detailed examination and analysis.

STUDENTS

Recording is...

✔ carefully collecting and organizing data so that it is easy to understand

✔ capturing as much pertinent information as possible—observations and results—using a variety of methods

✔ using graphic organizers. These should be developed by students so that they understand them and know how to use them.

✘ **not** jotting down random points, which can lead to confusion

✘ **not** recording sentence fragments, which are hard for others to understand. These may be difficult for even the recorder to decipher if too much time passes after the experiment.

TEACHERS

Recording is...

✔ allowing students to choose what to record and how, but promoting the use of certain categories to collect and organize data when necessary.

✔ monitoring students' record-making and suggesting better ways to record results and observations

✔ modeling the use of various methods and organizers to collect, maintain, and protect (back up) data

✔ an opportunity to assess students' understanding of the experimental design and required measurements

✘ **not** the final stage of an experiment. More learning comes from analyzing the results and drawing out conclusions.

✘ **not** one-size-fits-all data collection forms that everyone uses

WHAT THIS SKILL SHOULD LEAD TO

Recording procedures, results, interpretations, and conclusions allows experiments to be replicated and validated by others. Recording raw results allows for later transformation of these results into graphs (to look for patterns or trends) or statistical tests (e.g., mean, median, mode) to look for statistically significant results. Recording information in various forms can lead to more questions, deeper thinking and, ultimately, a better understanding of science.

Planning

Definition:
Working systematically, regularly organizing for future, seeing possible results.

Planning is the process of developing and implementing a step-by-step approach or procedure. Plans should be detailed and replicable, but the planning process can often involve altering the plan as students work through the process.

STUDENTS

Planning is...

✔ identifying the purpose of the inquiry or the nature of the problem

✔ considering the time, facilities, and materials available and how best to use them; taking previous experiences into account when doing so

✔ reviewing and assessing options to look for areas of improvement

✔ considering, and perhaps testing, alternative approaches

✘ **not** following a prescribed set of instructions

✘ **not** 'winging it" or working haphazardly

TEACHERS

Planning is...

✔ scaffolding the planning process so that students gradually assume responsibility for designing, conducting, and interpreting their own investigations

✔ responding to student-identified needs and questions as curriculum concepts are uncovered

✔ providing a selection of materials, instruments and/or equipment, and other resources in anticipation of student needs

✔ ensuring that students' plans include appropriate safety measures

✘ **not** prescribing step-by-step instructions

WHAT THIS SKILL SHOULD LEAD TO

➔ A more thoughtful, considered approach to solving problems

➔ Effective time and resource management

➔ Independent learners and problem solvers

Designing

Definition:
The overall plan or strategy by which hypotheses / research questions and technological problems are answered (with or without innovation).

Designing is the overall plan or strategy for technological problem solving (with or without innovation). Designing typically uses a process called the design loop, which makes problem solving more effective. The design loop involves framing the problem to be solved, doing research, generating a possible solution, and carrying out modeling/prototyping. An important part of the design loop is redesigning, which leads to improving the model/prototype.

STUDENTS

Designing is...

✔ identifying problems and opportunities through the analysis of real-world situations

✔ clarifying the problem and establishing design parameters

✔ gathering information through research

✔ generating a variety of solutions and choosing one to investigate

✔ developing a model/prototype and evaluating it

✔ improving and redesigning when necessary

✘ **not** the student lacking clarity about their approach to the problem. Initially, many students are prone to seeking hands-on solutions without forethought

✘ **not** scant organization or specificity in planning

TEACHERS

Designing is...

✔ explicitly teaching the design loop and gradually releasing responsibility to the students to direct their own problem solving

✔ monitoring the planning to ensure that it is directly connected to students' questions and goals

✔ encouraging concise designs that can be followed and reproduced by anyone else with the same or similar results

✘ **not** allowing haphazard approaches without plans

✘ **not** directing where the process will take place, identifying the precise materials required, or providing well-defined and numbered step-by-step instructions

WHAT THIS SKILL SHOULD LEAD TO

Students will master the procedural framework required to effectively solve technological problems. They will develop the ability to create designs with the precision expected in technological problem solving. At the primary level, designing may encompass just a few materials and a few basic steps and progress through the years to proficiency.

Gathering Data

Definition:
Collecting evidence through measurements, facts, figures, pieces of information, statistics (either historical or derived by calculation), experimentation, surveys, etc.

Inquiry requires that students collect information (qualitative and quantitative) to support their research, and gathering data is the process of getting that information. Students learn how to select what data to collect and what instruments to use to gather the data. Ultimately, conclusions need to be well supported by accurate and well-documented data to provide any meaningful insights into students' topics.

STUDENTS

Gathering data is...

✔ working independently or in groups to collect and record data for inquiry

✔ using a wide variety of data-gathering tools (e.g., scientific instruments/equipment, surveys, observation checklists, statistics, online databases, interviews) to collect data

✔ locating data through research and organizing it for their purposes

✔ using appropriate strategies (e.g., tables, checklists) to organize and record data so it can be easily retrieved and analyzed at a later time

✔ ensuring the information collected is accurate; using proper data collection methodologies

✔ taking steps to minimize bias in the data collected (e.g., randomly choosing samples)

✘ **not** watching someone collect data for them

✘ **not** exclusively using data provided by the teacher or in a textbook. In these cases, the teacher or textbook provides data-gathering tools and ways to organize the data.

✘ **not** copying data to a worksheet or from an overhead that was not generated in class

✘ **not** always collecting the same data as the rest of their classmates

TEACHERS

Gathering data is...

✔ making available scientific instruments/equipment and technology for students to select and use in their inquiries

✔ instructing students on the importance of accuracy (e.g., using a thermometer is superior to using touch) and quantity (e.g., multiple replications increase the reliability of the data)

✔ introducing data-gathering techniques. These can be modeled and explored before being used independently in investigations.

✘ **not** demonstrating an activity and having students record the results on pre-made worksheets

✘ **not** giving students primary or secondary data to analyze

✘ **not** telling students what data to collect, how to collect it, and how to best record it

WHAT THIS SKILL SHOULD LEAD TO

Students will be more engaged and will develop better data management skills.

Demonstrating

Definition:
Setting up apparatus, making it work, describing parts and functions, illustrating scientific principles.

Demonstrating requires students to use their thinking, planning, and investigation skills to show their comprehension of a specific concept(s). When students are responsible for illustrating a concept, they assume ownership of the task and are more likely to be engaged in the outcome.

STUDENTS

Demonstrating is...

✔ collaborating with peers and teachers to set up a presentation

✔ understanding the uses, limitations, and safety concerns of equipment and materials

✔ implementing appropriate safety procedures

✔ modifying equipment and materials to suit a specific purpose

✔ identifying key aspects of an event or situation for the audience

✘ **not** following specific instructions from a teacher or textbook

✘ **not** reading about an experiment or watching someone else perform it

TEACHERS

Demonstrating is...

✔ providing sufficient time and resources for students to plan and set up demonstration

✔ helping students acquire the necessary materials

✔ developing appropriate safety procedures

✔ giving students opportunities to investigate questions that arise

✔ an excellent opportunity to assess student understanding

✘ **not** having students watch *your* demonstrations

✘ **not** always detailing a specific set of materials and step-by-step procedures

WHAT THIS SKILL SHOULD LEAD TO

➜ Improved understanding about a concept

➜ Improved communication skills

➜ More competency at manipulating the materials and equipment used in the demonstration for the purposes of future investigation

Constructing

Definition:
Putting together component parts; to build or erect.

Constructing promotes spatial reasoning skills and the ability to follow plans and diagrams. Through hands-on construction, students develop an understanding of the properties and appropriate usage of tools and materials. Students also learn how to develop responsibility for their own tools and materials.

STUDENTS

Constructing is...

✔ hands-on!

✔ following plans and directions to assemble component parts

✔ using tools and materials safely

✔ building something, including a model or prototype, to solve a problem (technological problem solving)

✔ done independently or in small groups

✘ **not** done by an adult while students observe

TEACHERS

Constructing is...

✔ specifying building parameters

✔ encouraging precision and accuracy

✔ supervising activities closely

✔ developing and enforcing safety rules and routines

✔ having the necessary equipment

✔ encouraging students to rehearse and practice

✘ **not** teacher-directed

✘ **not** quiet, quick, or clean

WHAT THIS SKILL SHOULD LEAD TO

An ability to construct allows students to convert ideas into physical models. Constructing for an open-ended task develops creativity and problem-solving skills.

Inventing

Definition:
Designing something useful, for the first time, through the use of the imagination, ingenious thinking, and / or experimentation.

To invent is to contrive something new in response to a need or a problem through a combination of imagination, creativity, and experimentation. It encourages divergent thinking and develops higher-order thinking skills.

STUDENTS

Inventing is...

✔ recognizing a need and creating something to address that need

✔ using trial and error, making observations and predictions, planning and experimenting

✔ recording changes made and explaining why they were made

✔ thinking outside the box

✔ taking existing designs or objects and improving upon them in a significant way

✘ **not** creating something that already exists

✘ **not** following a set of instructions

✘ **not** building from a book, magazine, or website

✘ **not** assembling something that has been created by someone else

TEACHERS

Inventing is...

✔ presenting students with novel challenges

✔ allowing students to be purposefully loud and messy

✔ developing and enforcing safe practices

✔ being vigilant, so that students don't knowingly or unknowingly do anything unsafe

✘ **not** quick, quiet, or clean

✘ **not** teacher-directed

✘ **not** asking students to follow instructions from a book or video, though they may use such material

WHAT THIS SKILL SHOULD LEAD TO

Inventing develops the capacity to solve problems that don't yet exist and to seek opportunities in a future we cannot anticipate.

Experimenting

Definition:

Carrying out a designed investigation to test a hypothesis or answer a question.

Experimenting is the heart of scientific inquiry. It is the act of conducting a controlled test or investigation. Students manipulate equipment and materials to explore scientific theories and models. A properly designed experiment considers relevant variables. Students are more likely to experience success if they are practiced and familiar with the equipment and techniques required for the experiment. Insight into the science behind the experiment is gained through the evaluation of experimental results.

STUDENTS

Experimenting is...

✔ deliberately manipulating one characteristic of a situation or object to discover how it affects another characteristic

✔ designing and performing all of the steps involved in an inquiry-based investigation, including the question, associated variables, procedure, type of data to be collected, format for organizing and interpreting data, and the format in which results will be shared

✘ **not** following a recipe-type of experiment to recreate a known and predictable outcome

✘ **not** using a piece of equipment for the first time

✘ **not** letting another student/group do the experiment for you

TEACHERS

Experimenting is...

✔ providing rich experiences to help generate relevant, curriculum-based questions that students can explore

✔ giving students opportunities to solve a problem or answer a question by designing and performing their own experiment

✔ supporting students through the gradual release of responsibility by scaffolding the process of experimentation (e.g., Smarter Science Steps to Inquiry. PEOE, Problem Based Learning)

✘ **not** doing a demonstration for students

✘ **not** telling students what types of observations they should expect

✘ **not** distributing preprinted data collection tables

WHAT THIS SKILL SHOULD LEAD TO

➜ More engaged students

➜ Greater appreciation for precision, accuracy, and repeated trials in experimentation

➜ Increased ability to think critically about scientific and pseudo-scientific claims and the processes that support them

Analyze & Interpret

ANALYZE & INTERPRET

- Comparing
- Contrasting
- Classifying
- Outlining
- Graphing
- Analyzing
- Evaluating
- Reviewing

WHAT IT IS

- ◆ **Reviewing results carefully by examining data and identifying patterns**
- ◆ **Deciding what the results mean**
- ◆ **Evaluating and refining solutions**

PROCESS SKILLS

Comparing
Looking for similarities.

Contrasting
Looking for differences.

Classifying
Putting things into groups and subgroups, identifying categories, deciding between alternatives.

Outlining
Employing major headings and subheadings; using sequential, logical organization.

Graphing
Visually representing data.

Analyzing
Seeing implications and relationships, discerning causes and effects, locating new problems.

Evaluating
Recognizing good and poor features; judging and assessing.

Reviewing
Picking out important items, memorizing, associating.

Comparing

Definition:
Looking for similarities.

Comparing encourages students to notice subtle similarities in objects, events, behaviours, and data. Identifying similarities and differences (see 'Contrasting') between objects or events is a highly effective learning strategy that improves student achievement. In science, there are many opportunities for students to independently and effectively use this strategy.

STUDENTS

Comparing is...

✔ carefully examining two or more samples (objects, events, behaviours, or data)

✔ utilizing all five senses, as appropriate, to find similarities

✔ paying attention to finer details

✔ may involve graphic organizers to sort ideas

✔ may be influenced by prior knowledge, schema, or cultural perspective

✘ **not** only identifying simple and obvious similarities

✘ **not** always the same for every student—individuals may see and interpret things differently

✘ **not** looking for the 'right answer'

✘ **not** contrasting, which is looking for differences. However, comparing can often be done at the same time as contrasting.

TEACHERS

Comparing is...

✔ done by students, though you may need to provide prompts depending on their ages and abilities

✔ personal and individual to each student (consider previous experiences and cultural perspectives)

✔ differentiated for each student

✘ **not** expecting the same answer from everyone

✘ **not** limited to the obvious or simplistic

WHAT THIS SKILL SHOULD LEAD TO

Students will become better able to find patterns and commonalities, and thus become better and more keen observers of the natural world.

Contrasting

Definition:
Looking for differences.

Contrasting encourages students to notice subtle differences in objects, events, behaviours, and data. Identifying similarities (see 'Comparing') and differences between objects or events is a highly effective learning strategy that improves student achievement. In science, there are many opportunities for students to independently and effectively use this strategy.

STUDENTS

Contrasting is...

✔ carefully examining and determining differences between two or more samples (objects, events, behaviours, or data)

✔ sorting samples in multiple ways

✔ using graphic organizers (e.g., T-chart, Venn diagram, fishbone diagram) with headings to help sort or using the Frayer Model (focusing on differences) to help organize thinking and improve understanding of scientific content and concepts

✔ using differences in data to analyze and interpret results

✘ **not** only stating obvious differences

✘ **not** reporting things as being different without being able to communicate why

✘ **not** comparing, which is looking for similarities. However, contrasting can often be done at the same time as comparing.

TEACHERS

Contrasting is...

✔ giving students many opportunities to distinguish samples based on their differences

✔ using instructional strategies (e.g., gallery walk) so students can share their contrasting with other students

✔ allowing students to select samples and data that they can contrast. It is best if these come from student-directed inquiries

✔ differentiated for every student

✘ **not** supplying samples and data that have only obvious differences

✘ **not** expecting a single "right answer." Usually several correct responses will be possible.

✘ **not** always teacher-directed

WHAT THIS SKILL SHOULD LEAD TO

Students will become better able to find subtle differences in samples and thus become better at making quality observations. They will also generate better conclusions based on differences found in their inquiries. Through contrasting, students will learn useful descriptive vocabulary as well as develop higher-order thinking skills, such as the use of similes and metaphors, to communicate their understanding.

Classifying

Definition:
Putting things into groups and subgroups, identifying categories, deciding between alternatives.

Classifying helps students organize information to make sense of their world. Information that is sorted into carefully selected subgroups, based on group similarities, is easier to store, locate, and retrieve. Classification allows students to compare and contrast information and ideas.

STUDENTS

Classifying is...

✔ grouping any set of objects or concepts based on observable similarities (e.g., all living things)

✔ creating subgroups by identifying features that are different between subgroups (e.g., plants vs. animals)

✔ developing, testing, and defending sorting rules, using examples from the group as well as from the real world

✔ adjusting sorting rules to fit exceptional circumstances (e.g., plants are producers vs. animals are consumers)

✘ **not** sorting according to a published/teacher originated classification system

TEACHERS

Classifying is...

✔ encouraging students to discuss how items are similar and/or different

✔ students identifying key attributes and/or creating a rule, then needing to re-create or adjust the rule to fit other circumstances

✔ student-based (student-initiated activity with lots of discussion)

✔ an opportunity to make anecdotal notes and conference with students

✔ using or creating graphic organizers, including dichotomous keys or decision trees to arrange objects/observations

✘ **not** giving students the rules to sort by

✘ **not** providing a structured framework or key. This allows students to sort but not classify.

WHAT THIS SKILL SHOULD LEAD TO

Classifying involves the use of other skills, such as comparing and contrasting. Development of this skill leads to better observation and organization skills. Better questioning strategies also develop as a result of students' efforts to identify key attributes.

Outlining

Definition:
Employing major headings and subheadings; using sequential, logical organization.

An outline is a concise representation of key concepts. Outlines summarize the main and sub points of a presentation, lab report, argument, essay, poster, or any other presentation of information. Creating an outline is a useful first step in preparing to present the results of an investigation because it enables students to organize their thoughts before they prepare a first draft.

STUDENTS

Outlining is...

✔ creating a representation of the main points of a subject using text and/or graphics (e.g., arrows, diagrams, tables). Outlines are often written in point form and organized to identify main points and sub points.

✔ summarizing and logically organizing main points

✔ creating a skeleton that can be used to plan a more detailed presentation of information. An outline can be a list of the headings and subheadings for the final product.

✗ **not** a complete draft of an essay, lab report, or other presentation

✗ **not** written using complete sentences

✗ **not** haphazardly organized and difficult to follow

✗ **not** detailed

TEACHERS

Outlining is...

✔ an organized representation of ideas that allows the reader to see the entire presentation plan. Main and subpoints should be clearly identified.

✔ an opportunity to give students feedback early in the writing process, before they write a first draft

WHAT THIS SKILL SHOULD LEAD TO

The ability to create a good outline should lead to the more logical organization and presentation of information. Students who can convey the "big picture" or overview of their investigation in essays, lab reports, speeches, posters, and other presentations tend to be more successful at presenting and supporting their points succinctly. Good outlines ultimately lead to a more successful delivery of information.

Graphing

Definition:
Visually representing data.

Graphing is a visual representation of the data collected. It is presenting data in such a way that the reader better understands the relationships (including the identity of the dependent and independent variables) that were studied in the investigation. Graphing helps both the creator of the graph and the reader to recognize patterns and identify trends within the data.

There are many different types of graphs, each best suited to different types of data:

- **Bar graphs** — discrete data; to show comparisons among data
- **Histograms** — data that is organized in equal intervals
- **Line graphs and double line graphs** — data on a continuous scale, such as time or distance; to show change over time, which is the most common, but not the only, independent variable that can be graphed
- **Pictographs** — data that are multiples of a number; most appropriate for very young students
- **Pie graphs** — data that are percentages or fraction; to show parts of a whole
- **Stem and leaf graph** — data that involve place values

STUDENTS

Graphing is...

✔ presenting data in a visual way

✔ selecting the appropriate type of graph for the data

✘ **not** thinking that any type of graph will work for the given set of data

TEACHERS

Graphing is...

✔ modeling the creation of a graph

✔ teaching students about different types of graphs

✔ reading and analyzing graphs with students

✔ helping students to properly display independent and dependent variables on the appropriate axis

✘ **not** assuming that students know how to represent data appropriately

WHAT THIS SKILL SHOULD LEAD TO

Graphing can lead to a better analysis of data. Graphs can also help students to make conclusions about the results of their investigations. Students with advanced graphing skills can include standard deviations and equations of lines with their graphs.

Analyzing

Definition:
Seeing implications and relationships, discerning causes and effects, locating new problems.

Scientific investigation generates many forms of data. Analyzing this data means identifying trends and relationships between variables, generating new questions or problems to explore, and making connections to the real world. Analyzing the results of inquiries and investigations builds competency in scientific inquiry and allows students to better understand key concepts and principles involved in the inquiry.

STUDENTS

Analyzing is...

✔ reviewing the investigation—what happened and why/how

✔ working with the data to identify trends, do calculations if necessary, and draw conclusions

✔ interpreting the data in different ways

✔ developing next steps based on questions that arise during the investigation

✔ searching for patterns, concrete and abstract, that represent what actually occurred

✔ getting unexpected results in an inquiry, and examining or assessing why those results occurred

✘ **not** merely number-crunching; science is more than numbers and sometimes the most important data to be analyzed do not involve numbers at all

TEACHERS

Analyzing is...

✔ expecting and accepting varying results. The results of similar investigations can be very different depending on the many decisions students make in the course of conducting the investigation.

✔ prompting students to reflect on the investigation and giving them adequate time to do so: Did they get the results they expected? Can the results be explained? Where could the experimental method be improved? Are there any possible sources of error?

✔ using differentiated instruction—offering students more than one way to analyze the data

✔ giving students an opportunity to see other students' work, using strategies such as gallery walks, and to analyze the findings of the class

✔ taking the opportunity to assess students' learning, as reflected in their analysis

✔ providing enrichment opportunities for students to explore on their own time, to make stronger connections between what they have learned and new questions that have arisen

✘ **not** a quick step in scientific inquiry but rather the stage where students develop their understanding of the investigation and the concepts involved. It is important to give students adequate time for analyzing; not all students analyze data at the same rate.

WHAT THIS SKILL SHOULD LEAD TO

Analyzing data leads students to evaluate the validity of their findings and to check their results against their cognitive schema (i.e., Do the results make sense to me, and can I explain them?). Once the analysis is completed, students can communicate their findings in various ways to others.

Smarter Science: Introducing the Framework

Evaluating

Definition:
Recognizing good and poor features; judging and assessing.

To become informed citizens, students must learn to evaluate the ever-increasing amount of scientific information being produced and disseminated. Evaluating investigations means examining their methodologies, data collection, data analysis, and conclusions in order to identify strengths and weaknesses. Evaluation also helps investigators decide what to investigate next.

STUDENTS

Evaluating is...

✔ developing and using criteria to identify strengths and weaknesses in their own inquiries: methodologies, instruments used, data collection procedures, data analysis, and conclusions

✔ improving their inquiry design by reflecting on their evaluations (meta-cognition)

✔ reflecting on their use of process skills and their performance in class; using evaluations and judgments for personal growth

✔ using criteria and evidence to identify strengths and weaknesses in the inquiries of others

✔ explaining what they think and believe in their own words

✘ **not** making judgments based on personal preference or gut feeling

✘ **not** making global judgments about an inquiry without looking at the various components

TEACHERS

Evaluating is...

✔ modeling how to construct criteria, then gradually releasing responsibility for criteria construction to students

✔ giving students opportunities to evaluate and discuss scientific designs; giving them investigations to judge

✔ giving students opportunities to explore engaging, authentic activities that are relevant and meaningful to them. These can include case studies that explore multiple perspectives on scientific concepts.

✔ encouraging open-ended inquiry where students are expected to evaluate procedures and results

✔ valuing the skill of reflection by having students assess themselves and their peers

✘ **not** consistently providing hands-on experiences that have obvious conclusions, e.g., confirmation investigations

✘ **not** asking lower-order questions that require only retrieval of information, guessing, or identifying a preference

WHAT THIS SKILL SHOULD LEAD TO

Evaluating helps students consolidate the learning from their own investigations and will improve their future inquiries. Ultimately, students will become critical consumers of scientific information.

Reviewing

Definition:
Picking out important items, memorizing, associating.

Reviewing is looking back over what you have done over the course of an investigation to pick out key points, make connections, and find relationships between key components. By re-examining their methodologies and results, students can analyze the validity of their investigation. They also learn to identify further questions for investigation in the future. It is at this time that students consolidate their "personal bank" of information/skills.

STUDENTS

Reviewing is...

✔ picking out key facts and information

✔ perusing information carefully and thoroughly

✔ making connections between key content and concepts

✔ listing new questions that have arisen as a result of their investigation

✔ identifying directions for future investigation

✘ **not** just reading your notes over once

✘ **not** highlighting every word on the page

TEACHERS

Reviewing is...

✔ to be done independently, in pairs, and/or in small groups

✔ encouraging students to justify their choices of key points

✔ encouraging students to use multiple reviewing strategies e.g., mnemonic devices, acronyms, music, concept maps

✔ encouraging students to make personal jot notes identifying key points

✔ encouraging students to make connections between key elements

✘ **not** reading information to the class and indicating which parts are important

✘ **not** teacher initiated

✘ **not** providing the 'right answer'

WHAT THIS SKILL SHOULD LEAD TO

Students will become more able to recognize key concepts and ideas. They will hone their ability to make connections—concept to concept, self to concept, concept to world—and thus become more aware of their own understanding (metacognition). This in turn will make them more independent learners.

Communicate

WHAT IT IS

◆ **Explaining procedures and results through writing, speaking, visual or electronic means**
◆ **Reflecting on the process and checking with peers**

PROCESS SKILLS

COMMUNICATE

Discussing
Engaging in oral, written, or any other appropriate form of communication with others.

Explaining
Clearly describing, clarifying main points, and focusing on the "why" and/or "how" of the issue, concept or idea.

Reporting
Organizing and presenting information in a written or oral format.

Writing
Conveying information (e.g., questions, observations, experimental report) by graphical means.

Reflecting
The activity of either an individual or group that involves analyzing, judging the importance of, and making connections to the learning experience.

Teaching
Making meaning of concepts or processes by organizing them into key facts and ideas and clearly conveying them to others.

Discussing

Explaining

Reporting

Writing

Reflecting

Teaching

Discussing

Definition:
Engaging in oral, written, or any other appropriate form of communication with others.

Discussing is sharing and exchanging ideas with others. It is an opportunity to use various communication and thinking skills, such as summarizing, analyzing, concluding, theorizing, reflecting, and connecting. Discussions can be oral, but they can also occur in writing. Discussions are often by oral and multimedia presentations (e.g., slides, video, a demonstration). What students know about an inquiry and how well they understand it will clearly reveal itself in a discussion.

Purposes of a discussion include persuading others to accept or reject a hypothesis or idea, testing ideas, soliciting feedback, and exploring other points of view.

STUDENTS

Discussing is...

✔ sharing and interpreting collected data to make sense of it; analyzing whether the data supports or disproves their hypothesis

✔ listening carefully to what others say

✔ talking about problems that may have influenced the results and possible ways to correct them in the future

✔ making connections between their results, previous research, and existing theories

✔ debating or exchanging views about a concept

✔ evaluating the impact of the results and their applications in the real world

✔ generating new questions that may lead to further investigation

✘ **not** one-way communication

✘ **not** making remarks or stating conclusions that are not supported by evidence uncovered through investigation

TEACHERS

Discussing is...

✔ giving students opportunities to share and exchange ideas about their investigations

✔ prompting students to be clear and precise, and to use the appropriate scientific vocabulary

✔ prompting students to choose the best facts to support their ideas

✔ ensuring that discussions in written form (e.g., comments on blogs or social networks such as Ning) have structure and flow

✘ **not** allowing students to use language that is vague or inappropriate

WHAT THIS SKILL SHOULD LEAD TO

Discussion allows students to expand their knowledge about a topic and understand different points of view. They learn to express themselves precisely and to explain their reasoning (e.g., how they arrived at their conclusion). Debate is a healthy part of the scientific enterprise, and discussions are an effective way to explore opposition and skepticism.

Explaining

Definition:
Clearly describing, clarifying main points, and focusing on the "why" and/or "how" of the issue, concept or idea.

Explaining is not retelling an investigation but focusing on why and/or how something happened. Explaining allows students to communicate their understanding of a scientific concept to peers and teachers. It links literacy and numeracy skills to science, and develops key communication skills necessary in the real world.

STUDENTS

Explaining is...

✔ focusing on "why" and/or "how"

✔ choosing how to express ideas

✔ an opportunity to be creative and original

✔ creating suitable rubrics for the assessment of their explanation

✘ **not** a brief description of the investigation and its setup that doesn't demonstrate understanding, explain the importance of the investigation, and make connections to the real world

TEACHERS

Explaining is...

✔ letting students choose the way in which they will explain their investigation, results, and conclusions (e.g., choice board)

✔ supporting students' efforts to use precise vocabulary, and to express themselves effectively and succinctly

✔ an opportunity to assess student learning

✘ **not** a lab report or oral presentation

WHAT THIS SKILL SHOULD LEAD TO

Explanation leads to increased retention of the information explained, a deeper understanding of the ideas presented, improved communication skills, and a better use of scientific terminology.

Reporting

Definition:
Organizing and presenting information in a written or oral format.

Reporting is organizing and presenting the information students have gathered over the course of their inquiry, through direct observation, from interviews, from the examination of reports and documents, and from databases and Internet sources. Good reporters communicate clearly and concisely. Often, this skill is developed while collaborating with other students.

STUDENTS

Reporting is...

✔ sharing ideas, based on facts and evidence, with others

✔ using creative and original presentation formats

✔ using an extensive vocabulary, yet writing or speaking succinctly

✔ giving others the opportunity to understand the world as the reporter does

✘ **not** copying out of a book or from the board

✘ **not** using a specific format or graphic organizer

✘ **not** limited to journal/diary entries

TEACHERS

Reporting is...

✔ encouraging connections, inferences, and predictions

✔ promoting the sharing of ideas and evidence in a logical and concise manner

✔ encouraging creativity and the use of technology

✔ differentiated. Permitting and encouraging different presentation formats allows all students to successfully communicate their findings.

✔ scaffolding the process for students. Students can start by using a structured report format which evolves into a more sophisticated self-structured format.

✔ a natural literacy link

✘ **not** asking for patterned answers

✘ **not** requiring the same answer(s) or presentation format from everyone

WHAT THIS SKILL SHOULD LEAD TO

Students acquire research, speaking, and presenting skills through reporting. It is this step in an inquiry that establishes the factual and investigative background that informs their investigation. They gain an improved sense of logical sequences and often improve their ability to use vocabulary. A skilled reporter knows how to summarize background information and present it in a manner that piques the audience's interest.

Definition:
Conveying information (e.g., questions, observations, experimental report) by graphical means.

Writing is one form of communication that students use to present the process and results of their investigations, either in a written report, multimedia presentation, or oral presentation. In writing about their inquiries, students mirror the process used in a "real life" scientific community. By clearly communicating their data, investigative results, and the evidence supporting their conclusions, students reflect on the process of their inquiry. Other students also have the opportunity to question the results based on their own understanding, which can lead to rich discussions.

STUDENTS

Writing is...

✔ organizing data and presenting it in a logical format

✔ justifying results using evidence from the investigation

✔ asking new questions that arise from the investigation

✔ reflecting on discrepant or unexpected events and possible sources of error

✔ making recommendations for future investigations

✘ **not** answering specific questions written by the teacher

✘ **not** "fixing" data to agree with hypotheses

TEACHERS

Writing is...

✔ an opportunity to clarify thinking and understanding of concepts

✔ a natural literacy link

✘ **not** providing set questions for students to answer

✘ **not** a close-ended investigation

WHAT THIS SKILL SHOULD LEAD TO

Communicating their results to a wider audience helps students understand the difference between the results of an investigation and the conclusions drawn from it. Students learn to apply new knowledge to other situations, use evidence from research and investigation to support their conclusions, and address new questions that arise from the investigation. Understanding the process of writing to communicate investigations should help students to be more critical of published research.

Reflecting

Definition:
The activity of either an individual or group that involves analyzing, judging the importance of, and making connections to the learning experience.

The ability to reflect upon individual actions or ideas is an essential life skill. Such self-monitoring, or meta-cognition, has been identified as a key component of successful science learning. After performing a scientific inquiry, it is necessary to reflect upon the process, make links to key concepts, identify ideas that are poorly understood or require clarification, and determine how new learning fits with previously held beliefs.

STUDENTS

Reflecting is...

✔ examining the results of an investigation and developing questions that could be answered in future investigations

✔ recognizing connections between the investigation and course material

✔ working independently or as a group to determine the applications of the investigation

✘ **not** a chance for students to express their likes and dislikes about the investigation

TEACHERS

Reflecting is...

✔ having students brainstorm possible future investigations

✔ looking back at completed inquiries to identify possible problems or areas for improvement

✔ having students work independently or in groups to judge the validity of an investigation and connections to the course material

✔ providing a structured template to guide students through the reflective process

✘ **not** giving students ideas for future investigations

WHAT THIS SKILL SHOULD LEAD TO

Reflection should be an ongoing process. Ultimately, it should lead students to a better understanding of themselves as learners. In the context of science, reflecting gives students opportunities to integrate new concepts into existing schemas, ask new questions, and develop a better understanding of the processes of science.

Teaching

Definition:
Making meaning of concepts or processes by organizing them into key facts and ideas and clearly conveying them to others.

Teaching is a higher-order thinking skill that helps to develop a deeper understanding of materials. Collaboration is often an essential requisite. The student develops self-confidence, organizational skills and speaking/communication skills. When a student teaches, the process invariably strengthens their recall and understanding.

STUDENTS

Teaching is...

✔ communicating ideas clearly and with understanding to peers

✔ using own words to explain ideas

✔ focusing on key ideas and concepts

✔ accepting constructive (not destructive) criticism from peers

✔ providing visual aids and using different formats and tools (e.g., art, poetry, music, drama, technology) to illustrate ideas and concepts

✘ **not** reading from a book

✘ **not** a simple lecture

✘ **not** a paper-and-pencil activity

✘ **not** using videos from online sources created by others to teach a concept (though videos are an appropriate way to support an idea being taught)

TEACHERS

Teaching is...

✔ student-directed (though the teacher maintains responsibility for class management)

✔ time consuming

✔ encouraging students to use active learning and hands-on activities, and to explore different presentation formats to find those are most effective in teaching a particular concept

✔ providing the criteria for an effective teaching outcome

✘ **not** a substitute for teacher support, guidance, or instruction

✘ **not** one student standing in front of the class reading a paper for 30 minutes

✘ **not** prescribing exactly what needs to be taught and how to best teach it

WHAT THIS SKILL SHOULD LEAD TO

To teach, students must think and act like guides, facilitators, and advisers. They will develop better communication and organization skills as a result. They will also develop the ability to recognize key concepts and ideas and share them with others. Students should be challenged to develop teaching skills so that they can use the many forms of communication available to them most effectively.

Glossary

Bloom's taxonomy

The six levels of thinking categorized by Dr. Benjamin Bloom, starting at lower-level thinking (knowledge and comprehension) and progressing into higher-level thinking (application, analysis, synthesis, and evaluation). The type of thinking required at each level becomes more complex as you go from knowledge (e.g., memorize, label, define) to evaluation (e.g., compare, appraise, justify).

Choice board

A board with a number of activities or tasks that students choose from to show their own learning. Choice boards can be developed based on multiple intelligences or Bloom's taxonomy.

Frayer model

A visual organizer to aid the understanding of key words and concepts.

definition	characteristics
examples	non-examples

(center: word)
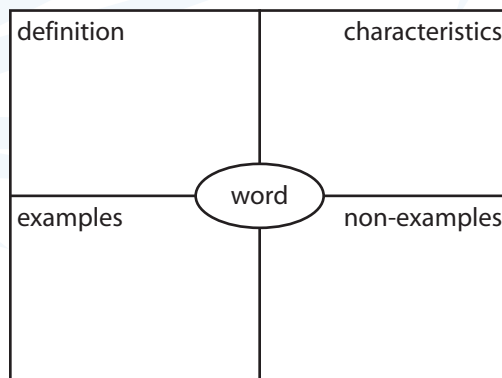
Gallery walk

An instructional or reflective strategy where students visit information or media stations around the room to look, discuss, and respond to. This can be teacher-directed, where the teacher sets up the stations, or it can be used to showcase students' learning through projects, activities, and experiments.

K-W-L chart

A strategy where students, at the beginning of a new unit or topic, record what they know and what they wonder or want to know about a topic. As they progress through the unit, students continue to record what they learn. K-W-L charts are valuable for pre-assessments and help students reflect on their learning.

Know	Want to Know	Learned

Predict—Explain—Observe—Explain (PEOE)

A teaching strategy used with demonstrations and experiments that requires students to make predictions about the outcome of an experiment; explain the reasons for, and thinking behind, their predictions; observe; and then reflect on their predictions, observations, and thinking. This strategy gives teachers and students information about student knowledge and thinking and encourages self-monitoring and reflection.

Problem-based learning

A learner-centred approach to address relevant, real-world problems or issues where the learner takes an active hands-on and minds-on approach and the teacher acts as a facilitator in the learning.

Question chart

A graphic framework for creating questions based on Bloom's Taxonomy. Questions are created by choosing a question word on the left and a verb from the top of the chart. As you move down and to the right, the questions become increasingly more complex and require higher-level thinking.

	Is	Did	Can	Would	Will	Might
What						
Where						
When						
Who						
Why						
How						

Schema

The prior or background knowledge and experience that a learner brings to a topic.

Venn diagram

A graphic organizer named after logician and philosopher John Venn that shows how two or more things are similar and different. Venn diagrams consist of two or more overlapping circles, where the overlapping area shows the common characteristics.
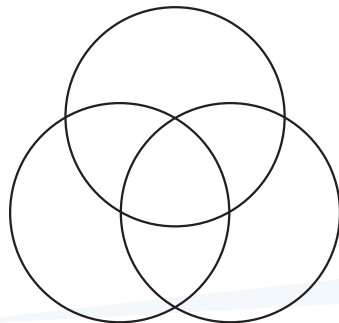
Credits

References

Bybee, Rodger W., Janet Carlson Powell, and Leslie W. Trowbridge. 2008. *Teaching secondary school science: strategies for developing scientific literacy*, 9th ed. Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.

Contributors

Tammy Adams, *Thames Valley District School Board*
Brad Digweed, *District School Board of Niagara*
Jennifer Dodds, *Thames Valley District School Board*
Colleen Fletcher, *Thames Valley District School Board*
Lise Goyette, *Thames Valley District School Board*
Bryan Honsinger, *District School Board of Niagara*
Stephanie Minor, *District School Board of Niagara*
Michael Newnham, *Youth Science Canada*

Reviewers

Michael Newnham, *Youth Science Canada*
Rick Pardo, *Thames Valley District School Board*
Brad Parolin, *Toronto District School Board*

Project Manager: Dimitra Chronopoulos
Editors: Dimitra Chronopoulos, Carol-Ann Freeman
Proofreader: Christa Bedwin
Design: Dave McKay