Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.1 Generate hypotheses on the basis of credible, accurate, and relevant sources of scientific information.
Taxonomy Level: 6.1-B Create Conceptual Knowledg**e**

Key Concepts: hypotheses, sources of scientific information

Previous/Future knowledge: Students were introduced to a hypothesis in 5th grade (5-1.1) as students identified questions suitable for generating a hypothesis. A more in-depth understanding of the processes and importance of using credible, accurate, and relevant sources of scientific information is expected for Biology. Generating hypotheses is the basis for conducting scientific investigations and is therefore vital to the understanding of the scientific inquiry process.

It is essential for students to

- Know that a hypothesis is a reasonable explanation of an observation or experimental result or a possible answer to a scientific question that can be tested. The hypothesis may or may not be supported by the experimental results. It is often stated in terms of an independent and a dependent variable—or a "cause-effect relationship." Examples of hypotheses might include:
  - If a leaf has a greater surface area, then the rate at which it produces oxygen may increase.
  - As the volume of the lungs increases, the rate at which breathing occurs decreases.
  - At warmer temperatures, mold will grow faster on bread

  Know that the results of an experiment cannot prove that a hypothesis is correct. Rather, the results verify or refute the hypothesis. Valuable information is gained even when the hypothesis is not supported by the results. For example, it would be an important discovery to find that lung capacity is not related to breathing rate. When hypotheses are tested over and over again and not contradicted, they may become known as laws or principles.
- Use *credible* (trustworthy), *accurate* (correct – based on supported data), and *relevant* (applicable, related to the topic of the investigation) sources of scientific information in preparation for generating a hypothesis. These sources could be previous scientific investigations science journals, textbooks, or other credible sources, such as scientifically reliable internet sites.

Teacher Note:

Some sources of information are not based on credible scientific research and may contain information that is not accurate. Credible science investigations are published in journals that are reviewed by a panel of respected research scientists active in the field of science being studied. Teachers could help students identify credible sources of scientific information that may help them with background information for their hypotheses. Teachers must also caution students to be skeptical of website information and journal articles that are not referenced to credible sources of scientific research.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

It is not essential for students to

- Reference research from outside sources for every hypothesis written, but if scientific information is needed for generating a hypothesis, it must be credible, accurate, and reliable;
- Name specific journals or websites, but the understanding of what makes a source credible and reliable is part of this indicator;
- Understand the concept of the null hypothesis.

Assessment Guidelines:

The objective of this indicator is to *generate* hypotheses on the basis of credible, accurate, and relevant sources of scientific information, therefore, the primary focus of assessment should be for students to formulate a credible hypothesis for an investigation. Students must have an understanding of how the relationship between the independent and dependent variables are related in a hypothesis.

In addition to *generate*, assessments may require that students:

- *Identify* the variables involved in a hypothesis;
- *Use* data to determine whether a hypothesis was supported or not supported by that data;
- *Summarize* the criteria by which scientific information would be used to help generate the hypothesis.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.2 Use appropriate laboratory apparatuses, technology, and techniques safely and accurately when conducting a scientific investigation.
Taxonomy Level: 3.1-C Apply Procedural Knowledge

Key Concepts: laboratory apparatus, laboratory technology, laboratory techniques, scientific investigation

Previous/Future knowledge: Students were introduced to this topic with specific tools identified at each grade level as follows: (K-1.2) magnifiers and eyedroppers; (1-1.2) rulers; (2-1.2) thermometers, rain gauges, balances, measuring cups; (3-1.5) beakers, meter tapes and sticks, forceps/tweezers, tuning forks, graduated cylinders, graduated syringes; (4-1.2) compass, anemometer, mirrors, prism; (5-1.4) timing device and 10x magnifier; (6-1.1) spring scale, beam balance, barometer, sling psychrometer; (7-1.1) microscope; (8-1.6) convex lenses, plane mirrors, color filters, prisms, slinky springs. Using technology while conducting scientific investigations and specific laboratory techniques will also be an important component of developing laboratory skills essential.

It is essential for students to

- Use appropriately and identify the following laboratory apparatuses and materials:
  Apparatuses and materials appropriate for biology investigations:

  Balances, triple beam or electronic
  Beakers (50mL, 100 mL, 250mL)
  Chemicals & other consumable materials depending on planned laboratory investigations
  Erlenmeyer flasks
  Evaporating dishes
  Filter paper
  Forceps
  Funnels
  Graduated cylinders (10 mL & 100 mL)
  Hand lenses (magnifiers)
  Hot plates
  Measuring tools (metric rulers, meter stick, meter tapes, stop watch or timer)
  Microscopes (compound & dissecting)
  Microscope slides & cover slips, light source, lens paper
  Lab aprons, safety goggles, gloves
  pH indicator paper, pH buffer solution
  Prepared slides of normal cells, human cheek cells, onion root cells, bacteria, protists, fungi, sickle cell blood, whitefish blastula, etc.
  Pipettes / droppers
  Petri dishes
  Ring stand, ring clamp, and test tube clamp
  Stirring rods, spatulas, scissors, chemical scoop
  Stoppers – rubber, cork
  Test tubes, clamp, holder, and rack
  Test tube brushes
  Thermometers (alcohol, digital)
  Tongs (crucible, beaker)
  Watch glasses, spot plate
  Wire gauze with ceramic centers

- Use the identified laboratory apparatuses in an investigation safely and accurately with
  - Associated technology, such as
    - computers, calculators and other devices, for data collection, graphing, and analyzing data; and
  - Appropriate techniques that are useful for understanding biological concepts, such as Using a microscope appropriately

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

NOTE TO TEACHER: Other useful materials and apparatuses to support the standards include

Aquarium	Preserved specimens-various animals (jellyfish, lamprey, starfish, fetal pig) fungi (mushrooms, morels) plants (fern, poison ivy, legume, lily)
Computers with access to the Internet	
Centrifuge	Screw top jars or clean baby food jars
Chromosome simulation kits	
Incubator	Biological charts and models especially models of DNA
Refrigerator	Gel electrophoresis supplies (tray, chamber, & power supply
Water bath	Dialysis tubing, Parafilm, chromatography paper
Lamps, Gooseneck (for photosynthesis)	Mortar and Pestle
Field guides to living things and other biological reference books	

It is not essential for students to

- Cut or bend glass tubing or insert it in rubber stoppers;
- Understand how probeware from a specific manufacturer functions.

Assessment Guidelines:

The objective of this indicator is to ***use*** appropriate laboratory apparatuses, technology, and techniques safely and accurately, therefore the primary focus of assessments should be to determine the proper use of the apparatuses, technology, and techniques for scientific investigations. Students must show an understanding of how the apparatuses are used safely and accurately.

In addition to *use*, assessments may require that students:

- *Identify* an apparatus from a description or illustration;
- *Recognize* appropriate laboratory apparatuses, technology, and techniques for given procedures;
- *Recognize* safety guidelines associated with use of laboratory apparatuses, technology, and techniques;
- *Exemplify* appropriate apparatuses, technology, and techniques needed for a scientific investigation;
- *Infer* which laboratory apparatuses, technology, and techniques are appropriate for given procedures and that will produce accurate results.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.3 Use scientific instruments to record measurement data in appropriate metric units that reflect the precision and accuracy of each particular instrument.
Taxonomy Level: 3.1-C Apply Procedural Knowledge

Key Concepts:
Reading scientific measuring instruments:
graduated cylinders, balances, spring scales, thermometers, rulers
Measurement data
Metric units
Precision and accuracy

Previous/Future knowledge: In the 1st grade students used rulers "accurately and appropriately" (1-1.2) but only used standard English units of measurement. In the 2nd grade students used thermometers and balances (2-1.2). By the 3rd grade students used meter tapes and graduated cylinders (3-1.5) and by the 6th grade spring scales and beam balances are used (6-1.1). In Biology the students will record measurement data in appropriate metric units using the correct number of decimals by estimating the last digit on the measurement scale of the instrument. Significant figures will be addressed in Chemistry (C-1.1) or Physics (P-1.1).

It is essential for students to
- Read scientific instruments such as graduated cylinders, balances, spring scales, thermometers, rulers, meter sticks, and stopwatches using the correct number of decimals to record the measurements in appropriate metric units.
- The measurement scale on the instrument should be read with the last digit of the recorded measurement being estimated.
- Record data using appropriate metric units (SI units). They should be able to use prefixes; milli, centi, kilo.
- Understand that the more decimals in the recorded measurement, the greater the precision of the instrument.
    - An instrument that can be read to the hundredths place is more precise than an instrument that can be read to the tenths place.
    - A 100 mL graduated cylinder that is marked in 1 mL increments can be read exactly to the ones place with the tenths place being estimated in the recorded measurement.
    - A 10 mL graduated cylinder that is marked in 0.1 mL increments can be read exactly to the tenths place with the hundredths place being estimated in the recorded measurement.
    - The 10 mL graduated cylinder, therefore, is more precise than the 100 mL graduated cylinder.
- Understand that the terms *precision* and *accuracy* are widely used in any scientific work where quantitative measurements are made.
    - ***Precision*** is a measure of the degree to which measurements made in the same way agree with one another.
    - The ***accuracy*** of a result is the degree to which the experimental value agrees with the true or accepted value.
    - It is possible to have a high degree of precision with poor accuracy. This occurs if the same error is involved in repeated trials of the experiment.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

It is not essential for students

- to identify the number of significant figures in measurements or
- to understand their use in calculations;
- to understand the difference between systematic and random measurement errors, or
- to define the degree of uncertainty of measurements.

Assessment Guidelines:

The major objective of this indicator is to *use* scientific instruments to record measurement data in appropriate metric units reflecting the precision and accuracy of each instrument, therefore, the primary focus of assessment should be to apply proper procedures to using instruments and record the data from the instruments accurately. Assessment items will require that students understand precise and accurate measurements and that all measurement data must have appropriate metric units associated with the digits.

In addition to *use*, assessment may require that students:

- *Exemplify* precise and accurate measurements;
- *Compare* precise vs. accurate measurement data;
- *Summarize* accuracy and precision with specific scientific instruments in making measurements;
- *Infer* that measurements vary in precision and accuracy;
- *Identify* the appropriate instrument that meets the measurement need and appropriate precision for a designated experiment.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.4 Design a scientific investigation with appropriate methods of control to test a hypothesis (including independent and dependent variables), and evaluate the designs of sample investigations.

Taxonomy Level: 6.2-C Create Procedural Knowledge
5.2-B Evaluate Conceptual and Procedural Knowledge

Key Concepts:
Scientific investigation: Hypothesis, Independent variable, Dependent variable
Methods of control: Controlled variable, Control group

Previous/Future knowledge: In the 4th grade (4-1.3), students summarized the characteristics of a simple scientific investigation that tests one manipulated variable at a time. In the 5th grade (5-1.3), students planned and conducted controlled scientific investigations, manipulating one variable at a time. In the 6th and 7th grades (6-1.1 and 7-1.1), students conducted controlled scientific investigations, and in the 8th grade (8-1.1), students designed controlled scientific investigations. In the 7th grade (7-1.5), students explained the relationships between independent and dependent variables in controlled scientific investigations. While students identified questions suitable for generating a hypothesis (5-1.1) that could be answered through scientific investigation (7-1.2) and (8-1.4), in Biology students will design and evaluate designs of controlled scientific investigations to test a hypothesis with stated independent and dependent variables. In Chemistry (C-1.4) and in Physics (P-1.4) students will expand the idea of designing and evaluating scientific investigations.

It is essential for students to

- Design a controlled scientific investigation in which one variable at a time is deliberately changed and the effect on another variable is observed while holding all other variables constant.
  The steps in designing an investigation include:
  - Stating the purpose in the form of a testable question or problem statement
  - Researching information related to the investigation
  - Stating the hypothesis
  - Describing the experimental process
    - Planning for independent and dependent variables with repeated trials
    - Planning for factors that should be held constant (controlled variables)
    - Setting up the sequence of steps to be followed
    - Listing materials
    - Planning for recording, organizing and analyzing data
  - Planning for a conclusion statement that will support or not support the hypothesis
- Understand that scientific investigations are designed to answer a question about the relationship between two variables in a predicted "cause-effect relationship."
- Understand that the statement that predicts the relationship between an independent and dependent variable is called a *hypothesis*.
- Understand that the *independent variable* is the variable that the experimenter deliberately changes or manipulates in an investigation.
- Understand that the *dependent variable* is the variable that changes in an investigation in response to changes in the independent variable.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

- Understand that the independent variable is the "cause" and the dependent variable is the "effect" in the "cause-effect" relationship that is predicted.
- Understand that all the other possible variables in the investigation should be held constant so that only one variable (the independent) is tested at a time. The variables which are held constant are called *controlled variables*.
- Understand that the investigator should conduct repeated trials to limit random error in measurements.
- Understand that, when appropriate, a *control group* is set up as a basis of comparison to test whether the effects on the dependent variable came from the independent variable or from some other source.

It is also essential for students to

- Evaluate the design of an experiment by assessing whether the steps of the investigation are presented.
- Evaluate the methods by which the investigation was conducted to determine:
    - Whether independent and dependent variables are appropriate for testing the hypothesis;
    - Whether only one variable is changed at a time by the investigator;
    - Which variables are, or should have been, controlled;
    - Whether data was collected with adequate repeated trials, organized and analyzed properly;
    - Whether the conclusion is logical based on the analysis of collected data.

Teacher Note: Many science laboratory activities simply give students procedures to follow, data to collect and graph, and questions to answer that verify their learning of the concepts. Science learning can be more interesting to students if they are given the opportunity to explore and wonder "why" more often. If students conduct an investigation in which something unexpected or unusual happens and then are asked to predict why it happened, they feel more involved in the learning. Then, if they are asked to *design an experiment* to see if their prediction is correct, they will feel empowered by the activity. These activities are often called "Open Inquiry" or "Guided Inquiry" depending on how much instruction is provided. Teachers should encourage students to be curious and wonder why things happen. Science fair projects can be a perfect opportunity for students to conduct these kinds of activities. Instruction and guidance should be provided to insure that proper investigative procedures are followed.

It is not essential for students to

- Understand the null hypothesis process.
- Perform statistical analysis on the data to evaluate the experimental design.

Assessment Guidelines:

The first objective of the indicator is to *design* a scientific investigation with appropriate methods of control to test a hypothesis; therefore the primary focus of assessment should be for students to demonstrate understanding of the components of a properly designed scientific investigation.

In addition to *design*, students should be able to:

- *Classify* the types of variables and constants in a controlled investigation;
- *Summarize* the components of a controlled scientific investigation.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Another objective of this indicator is to *evaluate* the designs of sample investigations; therefore, the primary focus of assessment should be to critique the components of a controlled scientific investigation by determining whether the investigation has met the criteria for testing a particular hypothesis.

In addition to *evaluate*, students should be able to:

- *Interpret* the data to *infer* a relationship between the variables predicted by the hypothesis;
- *Interpret* the data to determine if the conclusion is valid;
- *Check* the investigation results to determine if the hypothesis is supported;
- *Relate* the hypothesis to an appropriate scientific investigation;
- *Identify* the components of a scientific investigation.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.5 Organize and interpret the data from a controlled scientific investigation by using mathematics, graphs, models, and/or technology.

Taxonomy Level: 4.2-B Analyze Conceptual Knowledge
2.1-B Understand Conceptual Knowledge

Key Concepts:

Data	Graphs
Controlled scientific investigation	Direct and Inverse variations (proportion)
Formulas	Models
Dimensional analysis	Technology

Previous/Future knowledge: In the 6^{th} grade, students analyzed and interpreted data to distinguish between an observation and inference (6-1.2). In the 7^{th} grade, students used graphs, tables, and charts to explain the relationship between independent and dependent variables (7-1.5) while they interpreted data to construct explanations and conclusions in the 8^{th} grade (8-1.3). In Biology B-1.1 and B-1.4, students generate hypotheses and design scientific investigations. This indicator (B-1.5) expands on these processes by requiring that students organize and interpret data using mathematics, graphs, models, and technology. Indicator B-1.7 requires that students evaluate results to refute or verify a hypothesis.

It is essential for students to

- Organize data which is collected from a controlled scientific investigation.
    - Data should be organized in charts which list the values for the independent variable in the first column and list the values for the dependent variable in a column to the right of the independent variable.

Example Charts:

Independent Variable	Dependent Variable

(Or)

Independent Variable				Dependent Variable
	Trial 1	Trial 2	Trial 3	
First value				
Second value				
Third value				
(other values)				

- Use graphs to organize data from controlled investigations.
    - Data should be recorded on a graph with the independent variable plotted on the “X” axis and the dependent variable plotted on the “Y” axis.
    - Choose scales for both the horizontal axis and the vertical axis.
        - There should be two data points more than is needed on the vertical axis.
        - The horizontal axis should be long enough for all of the data points to fit.
        - The intervals on each axis should be marked in equal increments.
    - Label each axis with the name of the variable and the unit of measure.
    - Title the graph.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

- Use the graphs to analyze and interpret data to determine a relationship between the dependent and independent variables.
    - A line graph is used for continuous quantitative data.
    - A bar graph is used for non-continuous data which is usually categorical.
    - A circle graph shows a relationship among parts of a whole. Circle graphs often involve percentage data.
- Recognize the implications of various graphs
    - A *direct variation* (or proportion) is one in which, one variable increases as the other increases or as one variable decreases the other decreases. A straight line with a positive slope indicates a direct relationship that changes at a constant rate. A greater slope indicates an increased rate of change. For example the number of bacteria growth over time.

    - An *inverse variation* (or proportion) is one in which the product of two quantities is a constant. For example the relationship between rabbits and foxes in an ecosystem. Over time, as the number of foxes increase the number of rabbits decrease then the number of foxes begin to decrease and the number of rabbits begin increase.

- Understand that a *scientific model* is an idealized description of how phenomena occur and how data or events are related. A scientific model is simply an idea that allows us to create explanations of how we think some part of the world works. *Models* are used to represent a concept or system so that the concept may be more easily understood and predictions can be made.
    - The model of a cell helps us understand the composition, structure, and behavior of cells.
    - No model is ever a perfect representation of the actual concept or system. Models may change over time as scientific knowledge advances.
- Understand that *technology* (tools or processes) can be used to develop better understanding of the science concepts studied. As technology improves, science concepts are studied more completely and more accurately.
- Understand how to organize and analyze data using technology such as graphing calculators or computers.

It is not essential that students memorize formulas for relationships between dependent and independent variables studied.

Assessment Guidelines:
The first objective of this indicator is to *organize* data from a controlled scientific investigation; therefore the primary focus of assessment should be to use graphs, charts, tables or models to organize the data into a structure that illustrates the relationship between the variables.

Another objective of this indicator is to *interpret* data from a controlled scientific investigation, therefore the primary focus of assessment should be to change one form of data representation into another meaningful representation.

In addition to *organize* and *interpret*, assessments may require that students:
- *Illustrate* the relationship between two variables in a scientific investigation;
- *Interpret* variable relationships using graphs, models, or technology;
- *Use the procedure* of dimensional analysis to change the units of measurement of data.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.6 Evaluate the results of a controlled scientific investigation in terms of whether they refute or verify the hypothesis.
Taxonomy Level: 5.1-B Evaluate Conceptual Knowledge

Key Concepts:
controlled scientific investigation
hypothesis

Previous/Future knowledge: Students planned and conducted controlled scientific investigations beginning in the 5th grade (5-1.3). They evaluated results to formulate valid conclusions beginning in the 5th grade (5-1.6), and they generated questions to formulate a hypothesis (5-1.1). In Biology, students are introduced to testing a hypothesis by designing a controlled scientific investigation (B-1.4) and organizing and interpreting data by using mathematics, graphs, models, and technology (B-1.5). In chemistry (C-1.6) students will expand their knowledge of scientific investigation by including what the possible sources of error might be. In physics (P-1.9) students will communicate and defend a scientific argument or conclusion.

It is essential for students to
- Understand that in a controlled scientific investigation the *hypothesis* is a prediction about the relationship between an independent and dependent variable with all other variables being held constant.
- Understand that results of a controlled investigation will either refute the hypothesis or verify it by supporting the hypothesis.
  - After the hypothesis has been tested and data is gathered, the experimental data is reviewed using data tables, charts, or graphical analysis.
  - If the data is consistent with the prediction in the hypothesis, the hypothesis is verified.
  - If the data is not consistent with the prediction in the hypothesis, the hypothesis is refuted.
- Understand that the shape of a graph can show the relationship between the variables in the hypothesis.
- Understand that if the data does support the relationship, the hypothesis is still always tentative and subject to further investigation. Scientists repeat investigations and do different investigations to test the same hypothesis because the hypothesis is always tentative, and another investigation could refute the relationship predicted.
- Understand that scientific laws express principles in science that have been tested and tested and always shown to support the same hypothesis. Even these laws, however, can be shown to need revision as new scientific evidence is found with improved technology, advanced scientific knowledge, and more controlled scientific investigations based on these.

It is not essential that students
- Develop new hypotheses if the results have refuted the tested hypothesis;
- Carry out statistical analysis on the collected data.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Assessment Guidelines:
The objective of this indicator is to *evaluate* results of a controlled scientific investigation in terms of whether they refute or verify/support the hypothesis, therefore, the major focus of the assessment should be to critique the data (tables, charts, and graphical analysis) from an investigation to determine if the results support the relationship predicted between variables in the hypothesis.

In addition to *evaluate*, assessments may require that students:
- *Infer* that a hypothesis is verified or refuted by the results of the investigation;
- *Compare* data that supports or refutes a hypothesis;
- *Explain* why the results of an investigation support or refute a hypothesis;
- *Analyze* the data from an investigation to see if it supports or refutes the hypothesis.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.7 Evaluate a technological design or product on the basis of designated criteria (including cost, time, and materials).
Taxonomy Level: 5.1-B Evaluate Conceptual Knowledge

Key Concepts:
Technological design or product
Criteria: cost, time, materials

Previous/Future knowledge: In the 5th grade (5-1.7), students used a simple technological design process to develop a solution or product. In the 6th grade (6-1.4), students planned and produced a solution or product using a technological design process which included identifying a problem, designing a solution or product, implementing the design, and evaluating the solution or product. Technological design will continue to be developed at a higher level in chemistry, and physics.

It is essential for student to

- Understand that technological designs or products are produced by the application of scientific knowledge to meet specific needs of humans. The field of engineering focuses on these processes.
- Understand that there are four stages of technological design:
  - Problem identification
  - Solution design (a process or a product)
  - Implementation
  - Evaluation
- Understand that common requirements within the solution design stage of all technological designs or products include:
  - Cost effectiveness or lowest cost for production;
  - Time effectiveness or the least amount of time required for production, and
  - Materials that meet specific criteria, such as:
    - Solves the problem
    - Reasonably priced
    - Availability
    - Durability
    - Not harmful to users or to the environment
    - Qualities matching requirements for product or solution
    - Manufacturing process matches characteristics of the material
- Understand that benefits need to exceed the risk.
- Understand that there are tradeoffs among the various criteria. For example, the best material for a specific purpose may be too expensive.

It is not essential for students to

- Recognize which field of engineering is involved with specific products or designs.
- Match specific materials that would be best for specific technological designs or products without being given characteristics of the given materials.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Assessment Guidelines:
The objective of this indicator is to *evaluate* a technological design or product on the basis of designated criteria, therefore, the primary focus of the assessment should be to critique a technological design or product to determine if it meets designated criteria.

In addition to *evaluate*, assessments may require students to:

- *Exemplify* the best product based on given criteria;
- *Analyze* the best product or design from a given set based on associated criteria.
- *Compare* given products or designs on the basis of given criteria to select the best.
- *Summarize* the qualities of the best product or design based on given criteria.
- *Infer* from given criteria and qualities which product or design matches best.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.8 Compare the processes of scientific investigation and technological design.
Taxonomy Level: 2.6-B Understand Conceptual Knowledge

Key Concepts:
Science, Technology
Scientific investigation
Technological design

Previous/Future knowledge: In the 5th grade and 6th grades, students used technological design process (5-1.7) and (6-1.3), and from the 4th grade (4-1.3) on up, students have summarized characteristics of controlled scientific investigations. In Biology (B-1.7), students evaluated technological designs or products. Building on this knowledge, students will compare processes of scientific investigations and technological designs. Scientific investigations and technological design will continue to be developed.

It is essential for students to

- Understand that *science* is a process of inquiry that searches for relationships that explain and predict the physical, living and designed world.
- Understand that *technology* is the application of scientific discoveries to meet human needs and goals through the development of products and processes.
- Understand that the processes of *scientific investigation* are followed to determine the relationship between an independent and dependent variable described by a hypothesis. The results of scientific investigations can advance science knowledge.
- Understand that the processes of *technological design* are followed to design products or processes to meet specified needs. The results of technological designs can advance standard of living in societies.
- Understand that, in general, the field of engineering is responsible for technological designs or products by applying science to make products or design processes that meet specific needs of mankind.
- The process of controlled scientific investigations:
  - Asks questions about the natural world;
  - Forms hypotheses to suggest a relationship between dependent and independent variables;
  - Investigates the relationships between the dependent and independent variables;
  - Analyzes the data from investigations and draws conclusions as to whether or not the hypothesis was supported.
- The technological design process is used to design products and processes that people can use. The process may involve:
  - A problem or need is identified
  - A solution is designed to meet the need or solve the problem identified.
  - The solution or product is developed and tested.
  - The results of the implementation are analyzed to determine how well the solution or product successfully solved the problem or met the need.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Some ways that the two processes might be compared:

Scientific Investigation	Technological Design
Identifies a problem – asks a question	Identifies a problem or need
Researches related information	Researches related information
Designs an investigation or experiment	Designs a process or a product
Conducts the investigation or experiment – repeated trials	Implements the design or the process – repeated testing
Analyzes the results	Analyzes the results
Evaluates the conclusion – did the results refute or verify the hypothesis	Evaluates the process or product – did it meet the criteria
Communicates the findings	Communicates the product or process

It is not essential that students
- Distinguish which field of engineering is associated with specific technological designs.

Assessment Guidelines:
The objective of this indicator is to ***compare*** the processes of scientific investigation and technological design; therefore, the major focus of assessment should be to detect the similarities and differences in the processes of controlled scientific investigation and technological design.

In addition to *compare*, students should be able to:
- *Exemplify* the processes of scientific investigation and technological design;
- *Classify* a process as either part of a scientific investigation or technological design given a description of the steps;
- *Summarize* steps that may be part of each process;
- *Illustrate* the processes of scientific investigation and/or technological design in words, diagrams or pictures;
- *Recognize* each process based on whether it advances scientific knowledge or designs products or processes that meet specific needs of mankind.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

B-1.9 Use appropriate safety procedures when conducting investigations.
Taxonomy Level: 3.2-C Apply Procedural Knowledge

Key Concepts:
Safety procedures
Investigations

Previous/Future knowledge: Since kindergarten, students have been expected to use appropriate safety procedures when conducting investigations. In Biology students are expected to use specific safety procedures associated with the investigations in the particular course.

It is essential for students to

- Practice the safety procedures stated in every scientific investigation and technological design problem conducted in the laboratory and classroom. Follow safety procedures regarding
  - Personal safety – follow only the designated lab procedures; be sure to understand the meaning of any safety symbols shown, wear proper clothing and shoes for the lab, use protective equipment (goggles, aprons,…), tie back loose hair, never eat or drink in lab room, use proper technique for touching or smelling materials, be careful when using sharps (any item that can puncture, cut, or scrape the skin.)
  - Work area safety – use only designated chemicals or equipment, keep work area clear and uncluttered, do not point heated containers at yourself or anyone else, be sure all burners or hot plates are turned off when the lab is finished, know the location and use of the fire extinguisher, safety blanket, eyewash station, safety shower, and first aid kit, disconnect electrical devices, follow clean-up procedures as designated by the teacher.
- Safely and accurately practice appropriate techniques associated with the equipment and materials used in the activities conducted in the laboratory and classroom (see B-1.2 for materials lists).
- Abide by the safety rules in the course safety contract.
- Report any laboratory safety incidents (spills, accidents, or injuries) to the teacher.

NOTE TO TEACHERS – safety while working with students:

- Textbooks have lists of "Safety Procedures" appropriate for the suggested activities. Students should be able to describe and practice all of the safety procedures associated with the activities they conduct.
- Teachers should weigh the "risks vs. the benefits" of doing any scientific investigation with students.
- Teachers should emphasize the investigation procedures, as well as the safety procedures before doing an activity.
- Lab safety rules should be posted in the classroom and laboratory where students can view them. Students should be expected to learn these rules and pass a test on them showing mastery. Students should understand the importance of these rules and conduct investigations by following them. Putting themselves or others in danger by not following a safety rule is not tolerated.
- Special Biological Precautions: Use only nonpathogenic varieties of bacteria. Seal all petri dishes with tape. Kill all cultures before disposing of them. Wear gloves when working with bacteria and other specimens. Never allow students to collect cheek cells or draw blood.
- Teacher should ensure proper disposal of all specimens.

Scientific Inquiry

B-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

NOTE TO TEACHERS – teacher responsibility regarding safety:

- Follow safety and facility guidelines as outlined in the
  - SC Lab Safety CD – CD and training available from the SC Department of Education,
  - Lab Safety flipchart, and
  - SC School Facilities Guide.
- Science laboratories should be equipped with the proper safety equipment.
- Students should be carefully instructed about laboratory safety rules and assessed to determine mastery of the appropriate techniques before doing any laboratory activities. (Textbooks have safety guidelines and safety notes are included with the laboratory activities.)
- Laboratory safety contracts should be signed by the students and their parents or guardians and kept on file to protect the teacher, school, and school district.
- Laboratory safety violations and accidents should be reported in writing with witness signatures to administrators, duplicated, dated, and kept on file.
- Materials Safety Data Sheets (MSDS) should be kept on file and accessible to all teachers for all chemicals in the laboratory areas. (Several science companies provide CDs with all their MSDS on them for distribution to all science teachers in the school.)
- Each school district and/or school should have a Chemical Hygiene Plan according to OSHA guidelines.

Assessment Guidelines

The objective of this indicator is to *use* appropriate safety procedures, therefore, the primary focus of the assessment should be for students to practice appropriate safety procedures. In this case, students must have an understanding of which safety procedures should be used with given investigations. Assessments may require that students understand which procedures are not appropriate for conducting investigations safely.

In addition to *use*, assessments may require that students:

- *Recognize* appropriate safety procedures for conducting investigations.
- *Exemplify* appropriate safety procedures for conducting investigations.
- *Classify* a procedure as an appropriate or not appropriate safety procedure associated with an investigation.
- *Illustrate* appropriate safety procedures for conducting investigations.