COMPETENCY 1.0 UNDERSTANDING HOW TO MANAGE LEARNING ACTIVITIES TO ENSURE THE SAFETY OF ALL STUDENTS

Skill 1.1 Understands safety regulations and guidelines for science facilities and science instruction

All science labs should contain the following items of safety equipment. The following are requirements by law.

- Fire blanket which is visible and accessible
- Ground Fault Circuit Interrupters (GFCI) within two feet of water supplies
- Emergency shower capable of providing a continuous flow of water
- Signs designating room exits
- Emergency eye wash station which can be activated by the foot or forearm
- Eye protection for every student and a means of sanitizing equipment
- Emergency exhaust fans providing ventilation to the outside of the building
- Master cut-off switches for gas, electric, and compressed air. Switches must have permanently attached handles. Cut-off switches must be clearly labeled.
- An ABC fire extinguisher
- Storage cabinets for flammable materials

Also recommended, but not required by law:

- Chemical spill control kit
- Fume hood with a motor which is spark proof
- Protective laboratory aprons made of flame retardant material
- Signs which will alert people to potentially hazardous conditions
- Containers for broken glassware, flammables, corrosives, and waste.
- Containers should be labeled.

It is the responsibility of teachers to provide a safe environment for their students. Proper supervision greatly reduces the risk of injury and a teacher should never leave a class for any reason without providing alternate supervision. After an accident, two factors are considered; foresight and negligence. **Foresight** is the anticipation that an event may occur under certain circumstances. **Negligence** is the failure to exercise ordinary or reasonable care. Safety procedures should be a part of the science curriculum and a well managed classroom is important to avoid potential lawsuits

The **"Right to Know Law"** covers science teachers who work with potentially hazardous chemicals. Briefly, the law states that employees must be informed of potentially toxic chemicals. An inventory must be made available if requested. The inventory must contain information about the hazards and properties of the chemicals. Training must be provided in the safe handling and interpretation of the Material Safety Data Sheet.

The following chemicals are potential carcinogens and are not allowed in school facilities:

> Acrylonitriel, Arsenic compounds, Asbestos, Bensidine, Benzene, Cadmium compounds, Chloroform, Chromium compounds, Ethylene oxide, Ortho-toluidine, Nickel powder, Mercury.

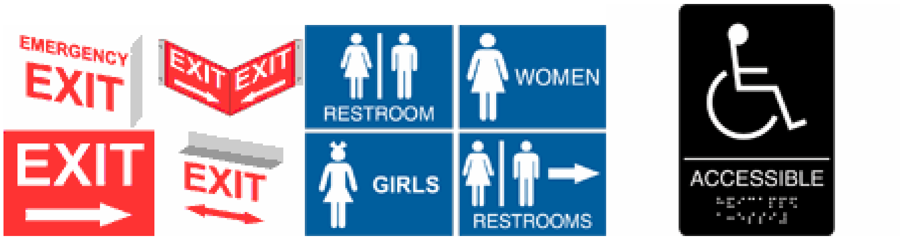
All laboratory solutions should be prepared as directed in the lab manual. Care should be taken to avoid contamination. All glassware should be rinsed thoroughly with distilled water before using, and cleaned well after use. Safety goggles should be worn while working with glassware in case of an accident. All solutions should be made with distilled water as tap water contains dissolved particles that may affect the results of an experiment. Chemical storage should be located in a secured, dry area. Chemicals should be stored in accordance with reactability. Acids are to be locked in a separate area. Used solutions should be disposed of according to local disposal procedures. Any questions regarding safe disposal or chemical safety may be directed to the local fire department.

Skill 1.2 Procedures and sources of information regarding the appropriate handling, use, disposal, care, and maintenance of chemicals, materials, specimens, and equipment.

Chemicals should not be stored on bench tops or heat sources. They should be stored in groups based on their reactivity with one another and in protective storage cabinets. All containers in the lab must be labeled. Suspect and known carcinogens must be labeled as such and segregated within trays to contain leaks and spills.

Chemical waste should be disposed in properly labeled containers. Waste should be separated based on their reactivity with other chemicals. Biological material should never be stored near food or water used for human consumption. All biological material should be appropriately labeled. All blood and bodily fluids should be put in a well-contained container with a secure lid to prevent leaking. All biological waste should be disposed of in biological hazardous waste bags.

In addition to the safety laws set forth by the government for equipment necessary to the lab, Occupational Safety and Health Administration (OSHA) has helped to make environments safer by instituting signs that are bilingual. These signs use pictures rather than/in addition to words and feature eye-catching colors. Some of the best-known examples are exit, restrooms, and handicap accessible.



Of particular importance to laboratories are diamond safety signs, prohibitive signs, and triangle danger signs. Each sign encloses a descriptive picture.

As a teacher, you should utilize a Material Safety Data Sheet (MSDS) whenever you are preparing an experiment. It is designed to provide people with the proper procedures for handling or working with a particular substance. MSDS's include information such as physical data (melting point, boiling point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective gear, and spill/leak procedures. These are particularly important if a spill or other accident occurs. You should review the MSDS, commonly available online, and understand the listing procedures. Material safety data sheets are available directly from the company of acquisition or the internet. The manuals for equipment used in the lab should be read and understood before initial use.

Skill 1.3 Knows procedures for the safe handling and ethical care and treatment of organisms and specimens.

Dissections - Animals that are not obtained from recognized sources should not be used. Decaying animals or those of unknown origin may harbor pathogens and/or parasites. Specimens should be rinsed before handling. Latex gloves are desirable. If gloves are not available, students with sores or scratches should be excused from the activity. Formaldehyde is a carcinogen and should be avoided or disposed of according to district regulations. Students objecting to dissections for moral reasons should be given an alternative assignment.

Live specimens - No dissections may be performed on living mammalian vertebrates or birds. Lower order life and invertebrates may be used. Biological experiments may be done with all animals except mammalian vertebrates or birds. No physiological harm may result to the animal. All animals housed and cared for in the school must be handled in a safe and humane manner. Animals are not to remain on school premises during extended vacations unless adequate care is provided. Many state laws stipulate that any instructor who intentionally refuses to comply with the laws may be suspended or dismissed.

Microbiology - Pathogenic organisms must never be used for experimentation. Students should adhere to the following rules at all times when working with microorganisms to avoid accidental contamination:

1. Treat all microorganisms as if they were pathogenic.
2. Maintain sterile conditions at all times

If you are taking a national level exam you should check the Department of Education for your state for safety procedures. You will want to know what your state expects of you not only for the test but also for performance in the classroom and for the welfare of your students.

COMPETENCY 2.0 UNDERSTANDING THE CORRECT USE OF TOOLS, MATERIALS, EQUIPMENT, AND TECHNOLOGIES

Skill 2.1 Select and safely use appropriate tools, technologies, materials, and equipment needed for instructional activities.

Bunsen burners - Hot plates should be used whenever possible to avoid the risk of burns or fires. If Bunsen burners are used, the following precautions should be followed:

1. Know the location of fire extinguishers and safety blankets and train students in their use. Long hair and long sleeves should be secured and out of the way.

2. Turn on the gas and make a spark with the striker. The preferred method to light burners is to use strikers rather than matches.

3. Adjust the air valve at the bottom of the Bunsen burner until the flame shows an inner cone.

4. Adjust the flow of gas to the desired flame height by using the adjustment valve.

5. Do not touch the barrel of the burner (it is hot).

Graduated Cylinder - These are used for precise measurements. They should always be placed on a flat surface. The surface of the liquid will form a meniscus (lens-shaped curve). The measurement is read at the <u>bottom</u> of this curve.

Balance - Electronic balances are easier to use, but more expensive. An electronic balance should always be tared (returned to zero) before measuring and used on a flat surface. Substances should always be placed on a piece of paper to avoid spills and/or damage to the instrument. Triple beam balances must be used on a level surface. There are screws located at the bottom of the balance to make any adjustments. Start with the largest counterweight first and proceed toward the last notch that does not tip the balance. Do the same with the next largest, etc until the pointer remains at zero. The total mass is the total of all the readings on the beams. Again, use paper under the substance to protect the equipment.

Buret – A buret is used to dispense precisely measured volumes of liquid. A stopcock is used to control the volume of liquid being dispensed at a time.

Light microscopes are commonly used in laboratory experiments. Several procedures should be followed to properly care for this equipment:

- Clean all lenses with lens paper only.
- Carry microscopes with two hands; one on the arm and one on the base.
- Always begin focusing on low power, then switch to high power.
- Store microscopes with the low power objective down.
- Always use a coverslip when viewing wet mount slides.
- Bring the objective down to its lowest position then focus by moving up to avoid breaking the slide or scratching the lens.

Wet mount slides should be made by placing a drop of water on the specimen and then putting a glass coverslip on top of the drop of water. Dropping the coverslip at a forty-five degree angle will help in avoiding air bubbles. Total magnification is determined by multiplying the ocular (usually 10X) and the objective (usually 10X on low, 40X on high).

Chromatography uses the principles of capillary action to separate substances such as plant pigments. Molecules of a larger size will move slower up the paper, whereas smaller molecules will move more quickly producing lines of pigments.

Spectrophotometry uses percent light absorbance to measure a color change, thus giving qualitative data a quantitative value.

Centrifugation involves spinning substances at a high speed. The more dense part of a solution will settle to the bottom of the test tube, while the lighter material will stay on top. Centrifugation is used to separate blood into blood cells and plasma, with the heavier blood cells settling to the bottom.

Electrophoresis uses electrical charges of molecules to separate them according to their size. The molecules, such as DNA or proteins, are pulled through a gel towards either the positive end of the gel box (if the material has a negative charge) or the negative end of the gel box (if the material has a positive charge).

Computer technology has greatly improved the collection and interpretation of scientific data. Molecular findings have been enhanced through the use of computer images. Technology has revolutionized access to data via the internet and shared databases. The manipulation of data is enhanced by sophisticated software capabilities. Computer engineering advances have produced such products as MRIs and CT scans in medicine. Laser technology has numerous applications with refining precision.

Satellites have improved our ability to communicate and transmit radio and television signals. Navigational abilities have been greatly improved through the use of satellite signals. Sonar uses sound waves to locate objects and is especially useful underwater. The sound waves bounce off the object and are used to assist in location. Seismographs record vibrations in the earth and allow us to measure earthquake activity.

Skill 2.2 The concepts of precision, accuracy, and error with regard to reading and recording numerical data from a scientific instrument.

Accuracy and precision

Accuracy is the degree of conformity of a measured, calculated quantity to its actual (true) value. Precision also called reproducibility or repeatability and is the degree to which further measurements or calculations will show the same or similar results.

Accuracy is the degree of veracity while precision is the degree of reproducibility. The best analogy to explain accuracy and precision is the target comparison.

Repeated measurements are compared to arrows that are fired at a target. Accuracy describes the closeness of arrows to the bull's eye at the target center. Arrows that strike closer to the bull's eye are considered more accurate.

Systematic and random error

All experimental uncertainty is due to either random errors or systematic errors.

Random errors are statistical fluctuations in the measured data due to the precision limitations of the measurement device. Random errors usually result from the experimenter's inability to take the same measurement in exactly the same way to get exactly the same number.

Systematic errors, by contrast, are reproducible inaccuracies that are consistently in the same direction. Systematic errors are often due to a problem, which persists throughout the entire experiment.

Systematic and random errors refer to problems associated with making measurements.

Mistakes made in the calculations or in reading the instrument are not considered in error analysis.

Skill 2.3 How to gather, organize, display, and communicate data in a variety of ways (e.g., charts, tables, graphs, diagrams, written reports, oral presentations.*).*

Graphing is an important skill to visually display collected data for analysis. The two types of graphs most commonly used are the **line graph** and the **bar graph** (histogram). Line graphs are used to illustrate the relationship between two variables. The horizontal axis is the X axis and represents the dependent variable. Dependent variables are those that would be present independently of the experiment. A common example of a dependent variable is time. Time proceeds regardless of anything else occurring. The vertical axis is the Y axis and represents the independent variable. Independent variables are manipulated by the experiment, such as the amount of light, or the height of a plant. Graphs should be calibrated at equal intervals. If one space represents one day, the next space may not represent ten days. A "best fit" line is drawn to join the points and may not include all the points in the data. Axes must always be labeled, for the graph to be meaningful. A good title will describe both the dependent and the independent variable. Bar graphs are set up similarly in regards to axes, but points are not plotted. Instead, the dependent variable is set up as a bar where the X axis intersects with the Y axis. Each bar is a separate item of data and is not joined by a continuous line.

Classification is grouping items according to their similarities. It is important for students to realize relationships and similarity as well as differences to reach a reasonable conclusion in a lab experience.

Normally, knowledge is integrated in the form of a **lab report**. A report has many sections. It should include a specific **title** and tell exactly what is being studied. The **abstract** is a summary of the report written at the beginning of the paper. The **purpose** should always be defined and will state the problem. The purpose should include the **hypothesis** (educated guess) of what is expected from the outcome of the experiment. The entire experiment should relate to this problem. It is important to describe exactly what was done to prove or disprove a hypothesis. A **control** is necessary to prove that the results occurred from the changed conditions and would not have happened normally. Only one variable should be manipulated at a time. **Observations** and **results** of the experiment should be recorded including all results from data. Drawings, graphs and illustrations should be included to support information. Observations are objective, whereas analysis and interpretation is subjective. A **conclusion** should explain why the results of the experiment either proved or disproved the hypothesis.

A scientific theory is an explanation of a set of related observations based on a proven hypothesis. A scientific law usually lasts longer than a scientific theory and has more experimental data to support it.

Skill 2.4 The international system of measurement (i.e., metric system) and performs unit conversions within measurement systems.

Science may be defined as a body of knowledge that is systematically derived from study, observations and experimentation. Its goal is to identify and establish principles and theories which may be applied to solve problems. Pseudoscience, on the other hand, is a belief that is not warranted. There is no scientific methodology or application. Some of the more classic examples of pseudoscience include witchcraft, alien encounters, or any topics that are explained by hearsay.

Science uses the metric system as it is accepted worldwide and allows easier comparison among experiments done by scientists around the world. Learn the following basic units and prefixes:

meter - measure of length
liter - measure of volume
gram - measure of mass

deca-(meter, liter, gram)= 10X the base unit	**deci** = 1/10 the base unit
hecto-(meter, liter, gram)= 100X the base unit	**centi** = 1/100 the base unit
kilo-(meter, liter, gram) = 1000X the base unit	**milli** = 1/1000 the base unit

COMPETENCY 3.0 UNDERSTANDING *THE* PROCESS OF SCIENTIFIC INQUIRY AND THE HISTORY AND NATURE OF SCIENCE

Skill 3.1 The characteristics of various types of scientific investigations

Most research in the scientific field is conducted using the scientific method to discover the answer to a scientific problem. The scientific method is the process of thinking through possible solutions to a problem and testing each possibility to find the best solution. The scientific method generally involves the following steps: forming a hypothesis, choosing a method and design, conducting experimentation (collecting data), analyzing data, drawing a conclusion, and reporting the findings. Depending on the hypothesis and data to be collected and analyzed, different types of scientific investigation may be used.

Descriptive studies are often the first form of investigation used in new areas of scientific inquiry. The most important element in descriptive reporting is a specific, clear, and measurable definition of the disease, condition, or factor in question. Descriptive studies always address the five W's: who, what, when, where, and why. They also add an additional "so what?" Descriptive studies include case reports, case-series reports, cross-sectional students, surveillance studies with individuals, and correlational studies with populations. Descriptive studies are used primarily for trend analysis, health-care planning, and hypothesis generation.

A **controlled experiment** is a form of scientific investigation in which one variable, the independent or control variable, is manipulated to reveal the effect on another variable, the dependent (experimental) variable, while all other variables in the system remain fixed. The control group is virtually identical to the dependent variable except for the one variable whose effect is being tested. Testing the effects of bleach water on a growing plant, the plant receiving bleach water would be the dependent group, while the plant receiving plain water would be the control group. It is good practice to have several replicate samples for the experiment being performed, which allows for results to be averaged or obvious discrepancies to be discarded.

Comparative data analysis is a statistical form of investigation that allows the researcher to gain new or unexpected insight into data based primarily on graphic representation. Comparative data analysis, whether within the research of an individual project or a meta-analysis, allows the researcher to maximize the understanding of the particular data set, uncover underlying structural similarities between research, extract important variables, test underlying assumptions, and detect outliers and anomalies. Most comparative data analysis techniques are graphical in nature with a few quantitative techniques. The use of graphics to compare data allows the researcher to explore the data open-mindedly.