**SCIENTIFIC INQUIRY STUDY GUIDE**

**Generate hypotheses on the basis of credible, accurate, and relevant sources of scientific information.**

* 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 support or do not support 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 investigationsscience journals, textbooks, or other credible sources, such as scientifically reliable internet sites.

**Use appropriate laboratory apparatuses, technology, and techniques safely and accurately when conducting a scientific**

**investigation.**

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

* 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, or
* probeware and meters to gather data; and
  + Appropriate techniques that are useful for understanding biological concepts, such as

Using a microscope appropriately

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.

2

**Use scientific instruments to record measurement data in appropriate metric units that reflect the precision and accuracy of each particular instrument.**

* 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.
* Understandthat 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.

**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.**

* 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.
* 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.
* 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.

3

**Organize and interpret the data from a controlled scientific investigation by using mathematics (including formulas and dimensional analysis), graphs, models, and/or technology.**

* 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.
* 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.



* An *inverse variation* (or proportion) is one in which the product of two quantities is a constant. For example the product of the frequency and the wavelength is equal to the velocity of a wave (v = f λ). Frequency and wavelength are inversely proportional. As one quantity increases the other quantity decreases.

4



Use a *formula* to solve for one variable if given the value for the other variables.

* Use *dimensional analysis* to change the units of the measurement determined, not the value of the measurement itself.
* It is very important in science to express all numbers with *units of measurement* when appropriate, not just the number as is sometimes done in purely mathematical problems.
* To change a measurement from liters to milliliters, or grams to kilograms, for example, the measurement can be multiplied by a “conversion factor” that expresses the relationship between the given and asked- for value.
* This conversion factor is a fraction equal to one and, therefore, the *value* of the original measurement does not change---only the *unit* changes.

15 ~~liters~~ X 1000 milliliters = 15,000 milliliters

1 ~~liter~~

(conversion factor)

15 ~~milliliters~~ X 1 liter = 0.015 liters

1000 ~~milliliters~~

* 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 the atom helps us understand the composition, structure, and behavior of atoms. Models for the atom can change as new information and theories explain the atom more completely.
  + 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/machines 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.

**Evaluate the results of a controlled scientific investigation in terms of whether they refute or verify the hypothesis.**

* 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 supported.
  + 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.

5

**Evaluate a technological design or product on the basis of designated criteria (including cost, time, and materials).**

* 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.

**Compare the processes of scientific investigation and technological design.**

* 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. 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 |

6

**Use appropriate safety procedures when conducting investigations.**

* 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.
* Abide by the safety rules in the course safety contract.

Report any laboratory safety incidents (spills, accidents, or injuries) to the teacher.

**RFM**