Student Lab Safety

Scientific Tools

Scientific inquiry often requires the use of tools. As you engage in scientific inquiry, you will need tools to help you take measurements. You might use one or more of them during a scientific investigation to collect, record, and analyze information. Always follow appropriate safety procedures when using scientific tools.

Glassware

Laboratory glassware is used to hold, pour, heat, and measure liquids. Most labs have many types of glassware. For example, flasks, beakers, graduated cylinders, petri dishes, test tubes, and specimen jars are used as containers.

Timing Devices

Scientists use stop-watches to measure the time it takes for an event to occur. A wall clock may also be used to monitor time while doing an investigation.

Triple-Beam Balance

Use a triple-beam balance to measure the mass of an object. Triple-beam balances are instruments that require some care when using. Follow your teacher's instructions so that you do not damage the instrument. Digital balances also might be used.

Hot Plate

A hot plate is a small heating device that can be placed on a table or desk. Hot plates are used to heat substances in the laboratory.

Computers

Scientists can collect, compile, and analyze data more quickly using a computers. Scientists use computers to prepare research reports and to share their data and ideas with investigators worldwide.

Calculators

A calculator is a scientific tool that you might use in math class. But you also can use it in the lab and in the field to make quick calculations using your data.

Metric Rulers, Tape Measures, and Metersticks

Use rulers, tape measures, and metersticks to measure lengths and distances. For small objects, such as pebbles or seeds, use a metric ruler with centimeter and millimeter markings. To measure larger objects, such as the height of a plant, use a meterstick. Use a metric tape measure for even longer distances, such as the length of your bedroom.

Spring Scale

A spring scale is used to measure the weight of an object. When an object is placed on the scale, the spring is extended. The distance the spring is pulled indicates the weight of the object.

Spectroscope

A spectroscope is used to measure the properties of light. Different substances give off a unique pattern of bands of color. As the light from a material passes through a spectroscope, it is separated into color bands.

Microscopes and Slides

Microscopes enable you to observe small objects that you cannot observe with just your eyes. The girl is looking into two eyepieces to observe a magnified image of a small object or organism. However, some microscopes have only one eyepiece. A microscope slide is used as a surface to hold whatever is being observed under the microscope.

Thermometers

A thermometer measures the temperature of substances. Use care when you place a thermometer into a hot substance so that you do not burn yourself. Handle glass thermometers gently so that they do not break. If a thermometer does break, tell your teacher immediately. Do not touch the broken glass or the thermometer’s liquid. Never use a thermometer to stir anything.

Anemometer

An anemometer is used to measure wind speed. The most common type of anemometer has three or four cups that spin around horizontally as wind blows. The cups are attached to a rod. The anemometer counts the number of rotations to determine wind speed.

Psychrometer

A psychrometer measures the relative humidity of the atmosphere. It consists of a wet- and dry-bulb thermometer. As the water on the wet bulb thermometer evaporates, the temperature on the thermometer is lowered. Once the water has evaporated, the temperature on both thermometers is recorded. These readings are used to determine the relative humidity.

Notebook

Use a science journal to record observations, questions, hypotheses, data, notes, and conclusions from your scientific investigations.

Reduce, Reuse, Recycle

Most pieces of equipment can be reused. They should be cleaned and stored accordingly. If a piece of glassware or other equipment breaks, ask your teacher how to properly dispose of it. Broken glassware, plastic, or other equipment may be able to be recycled.

In addition to the scientific tools used for investigations, there are numerous materials that may be required. It is important to use them appropriately. Many materials cannot be reused, and should either be thrown away or recycled. Chemicals should be disposed of in a safe and legal manner. Always ask your teacher how they should be disposed of, do not pour them in the sink. It is also important to use only the amount of materials you need. Follow the given quantities for each investigation so that you do not take more than is required. Conserving materials helps to ensure there will be enough for everyone to complete an investigation as written. When out in the field, take care to not leave anything behind.

Scientific Inquiry Methods for Lab and Field Investigations

When scientists conduct investigations, they use scientific inquiry. Scientific inquiry is a process that uses a set of skills to answer questions or to test ideas about the natural world. Scientific inquiry can be done either in a laboratory setting or outside in the field. A benefit of field investigations is seeing things in nature that cannot be studied in the classroom.

There are many kinds of scientific investigations, and there are many ways to conduct them. The three types of investigations in this manual are descriptive, comparative, and experimental. **A descriptive investigation** *involves asking a question, making observations, and recording data to draw conclusions.* Observations are recorded, but comparisons are not made and variables are not changed. In a **comparative investigation,** *varying data are collected so that comparisons can be made.* A hypothesis is written defining one independent variable and one dependent variable. It is important to ensure that only one variable, the independent variable, is changed at a time. This allows for a fair test and fairness in measuring variables. Now, the effect on the dependent variable caused by changing the independent variable can be determined. In an **experimental investigation,** *a control is identified in addition to the independent and dependent variables.* A control does not change for the entire investigation. This type of experiment is also known as a controlled experiment.

As scientists study the natural world, they ask questions about what they observe. To find the answers to these questions, they commonly use certain skills, or methods. However, it is important to know that, sometimes, not all of these skills are performed in an investigation, or performed in this order.

Make Observations and Ask Well-Defined Questions

One way to begin a scientific inquiry is to observe the natural world and ask questions. **Observation** *is the act of using one or more of your senses to gather information and taking note of what occurs.* Suppose you observe that the banks of a river have eroded more this year than in the previous year, and you want to know why. You also note that there was an increase in rainfall this year. The observations you've made allow you to make an inference. An **inference** *is a logical explanation of an observation that is drawn from prior knowledge or experience.* You infer that the increase in rainfall caused the increase in erosion. You decide to investigate further. You develop a hypothesis and a method to test it.

Formulate Testable Hypotheses

A **hypothesis** *is a possible explanation for an observation that can be tested by scientific investigations.* A hypothesis states an observation and provides an explanation. For example, you might make the following hypothesis: More of the riverbank eroded this year because the amount, the speed, and the force of the river water increased

When scientists state a hypothesis, they often use it to make predictions to help test their hypothesis. A **prediction** *is a statement of what will happen next in a sequence of events.* Scientists make predictions based on what information they think they will find when testing their hypothesis. For example, predictions for the hypothesis above could be: *If rainfall increases, then the amount, the speed, and the force of river water will increase. If the amount, the speed, and the force of river water increase, then there will be more erosion.* When you test a hypothesis, you often test whether your predictions are true. If a prediction is confirmed, then it supports your hypothesis. If your prediction is not confirmed, you might need to modify your hypothesis and retest it.

Test Your Hypothesis

Now that you have formed your hypothesis, you need to test it. During an investigation, you will make observations and collect data, or information. This data might either support or not support your hypothesis. A scientist needs to make many decisions before beginning an investigation. Some of these include: how to carry out the investigation, what equipment to use, what steps to follow, what technology to use, how to record the data, and how the investigation will answer the question.

Use Appropriate Equipment and Technology In order to know what materials to use, as well as how and in what order to use them, you must follow a procedure. Once the procedure is determined, the variables can be identified as well as how data will be collected. The type of data being collected will help you determine what equipment and technology to use in the investigation.

Use Models One way to help you better understand the parts of a structure, the way a process works, or to show things too large or small for viewing is to make a model.

For example, you may want to study the structure of a bridge, but you can't bring one into the classroom! Creating a scale model of a bridge allows you to study a smaller version of what a bridge looks like and how it works. You can build a model at whatever size you want. Seeing a model of an object that is larger than the actual object is an advantage, too. An atomic model made of a plastic-ball nucleus and chenille stem electron shells can help you visualize how the parts of an atom relate to each other. You might use the same materials of the actual structure in your model. Other types of models can be devised on a computer or represented by equations.

A disadvantage of models is that they are merely a representation of an object. Sometimes they cannot be made from the same material as an actual object and therefore may have different properties. Also, using a smaller scale could limit what types of tests you can conduct with the model. You could not test how the weight of a car affects a model of a bridge. You would need another scale model of the car to test.

Collect and Record Data

The **International System of Units** (SI) *is the internationally accepted system for collecting and recording measurements.* SI uses standards of measurement, called base units, which are shown in **Table 1.**

Table 1 SI Base Units

Quantity Measured	Unit (symbol)
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Electric current	ampere (A)
Temperature	kelvin (K)
Substance amount	mole (mol)
Light intensity	candela (cd)

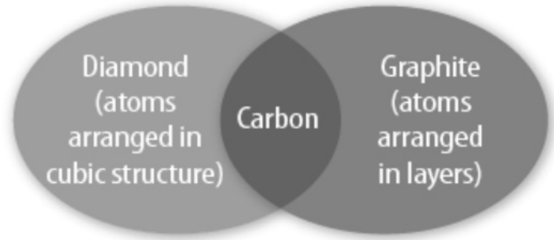
A base unit is the most common unit used in the SI system for a given measurement. In addition to base units, SI uses prefixes to identify the size of the unit, as shown in **Table 2.**

Table 2	**Prefixes**
Prefix	**Meaning**
Mega- (M)	1,000,000 or (10^6)
Kilo- (k)	1,000 or (10^3)
Hecto- (h)	100 or (10^2)
Deka- (da)	10 or (10^1)
Deci- (d)	0.1 or $\left(\frac{1}{10}\right)$ or (10^{-1})
Centi- (c)	0.01 or $\left(\frac{1}{100}\right)$ or (10^{-2})
Milli- (m)	0.001 or $\left(\frac{1}{1,000}\right)$ or (10^{-3})
Micro- (μ)	0.000001 or $\left(\frac{1}{1,000,000}\right)$ or (10^{-6})

Prefixes are used to indicate a fraction of ten or a multiple of ten. In other words, each unit is either ten times smaller than the next larger unit or ten times larger than the next smaller unit. For example, the *prefix deci–* means 10^{-1}, or 1/10. A decimeter is 1/10 of a meter. The prefix *kilo–* means 10^3, or 1,000. A kilometer is 1,000 m.

Scientists collect and record data as numbers and descriptions, and organize them in specific ways. Scientists observe items and events, and then record what they see. When they use only words or images to describe an observation, it is called qualitative data. Data may be shown in a labeled drawing or described in writing. Graphic organizers are another way to organize qualitative data. A Venn diagram is a graphic organizer that compares and contrasts two items as shown in **Figure 1.** Scientists' observations also can describe how much there is of something. These observations use numbers, as well as words, in the description and are called quantitative data.

Figure 1 This Venn diagram compares and contrasts two substances made from carbon.



One way to organize information so it is easier to understand is to use tables and graphs. Tables can contain numbers, words, or both. To make a table, list the items to be compared in the first column and the characteristics to be compared in the first row. The title should clearly indicate the content of the table, and the column or row heads should be clear. Notice that in **Table 1** the units are included. Some investigations require repeated trials of the same activity. After recording the data in a table, the mean, or average, of the data set can be calculated. Seeing data in a table also makes it easier to identify patterns in data collected. Data in tables can be displayed in a graph—a visual representation of data. Common graph types include circle graphs, bar graphs, and line graphs.

Bar Graph To compare data that does not change continuously you might choose a bar graph. A bar graph uses bars to show the relationships between variables. The x-axis variable is divided into parts. The parts can be numbers such as years, or a category such as a type of animal. The y-axis is a number and increases continuously along the axis.

Circle Graph To display data as parts of a whole, you might use a circle graph. A circle graph is a circle divided into sections that represent the relative size of each piece of data. The entire circle represents 100%, half represents 50%, and so on.

Line Graph A line graph, as shown in **Figure 2,** shows a relationship between two variables that change continuously. The independent variable is changed and is plotted on the *x*-axis. The dependent variable is observed, and is plotted on the *y*-axis.

Analyze, Evaluate, and Critique Scientific Explanations

Scientists formulate reasonable explanations based on data gathered. To determine the meaning of your observations and investigation results, you will need to look for patterns in the data. Then you must use logical reasoning to determine what the data mean. Once scientists have analyzed the data they collected, they then draw conclusions about the data. **A conclusion** *is a summary of the information gained from testing a hypothesis.* When you draw a conclusion, you must evaluate those conclusions to determine whether the data supports the hypothesis. If your data do not support your hypothesis, it does not mean that the hypothesis is wrong. It means only that the result of the investigation did not support the hypothesis.

Scientists critique scientific explanations to determine what may need further investigation. Maybe the experiment needs to be redesigned, or some of the initial observations on which the hypothesis was based were incomplete or biased. Perhaps more observation or research is needed to refine your hypothesis. A successful investigation does not always come out the way you originally predicted.

There are several ways scientists analyze, evaluate, and critique scientific explanations. They study empirical evidence and draw conclusions based on that information. Empirical evidence is data collected and recorded from observations. Scientists use logical reasoning when looking at evidence.

Figure 2 A line graph shows a visual relationship between two variables.

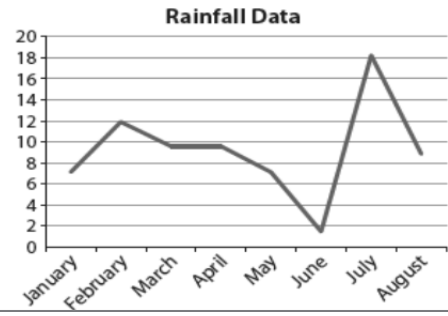


Table 3 Rainfall Data	
Month	**Amount**
January	7.11 cm
February	11.89 cm
March	9.58 cm
April	9.58 cm
May	7.11 cm
June	1.47 cm
July	18.21 cm
August	8.84 cm

By using information gathered by other scientists and combining it with what they have observed, scientists can draw their own conclusions about their investigations. Both experimental and observational testing are used to gather data. Recall that in observational testing, observations are made to collect data to answer a question—no variables are changed. In experimental testing, variables are manipulated. The data gathered are used to either support or not support a hypothesis.

Communicating Conclusions An important part of the scientific inquiry process is communicating valid conclusions. Including data to support conclusions helps validate your results. Results might be written in a science journal article, spoken at a science conference, or even shared on the internet. Scientists communicate results of investigations to inform other scientists about their research and the conclusions of their research. Scientists might apply each other's conclusions to their own work to help support their hypotheses.