Process Skills: Observing

Observing is using one or more of your senses to gather information about the world. Information gathered from observations is called evidence, or data. When you make observations in science, you want them to be accurate and objective. An *accurate* observation is an exact report of what your senses tell you. An *objective* observation avoids opinions, or bias, based on a specific point of view. *Quantitative* observations include numbers. *Qualitative* observations do not have numbers but include descriptions.

Hints for Making Observations

- **Be sure your observations are accurate and objective.**
- **You can record qualitative observations based on your sense of sight, hearing, touch, and/or smell. Safety First: NEVER taste any substance in the laboratory.**
- **Whenever possible, count or use instruments to make quantitative observations. Always include units, for example, for a mass measurement of 5 g or a distance measurement of 15 m.**
- **If no measuring instruments are available, estimate using known standards. For example, an object is about as long as a new pencil or about the mass of a paper clip.**

Practice Your Observing Skills

Put a check mark beside the observations you think are **accurate**.

Underline any that are **objective**.

Circle any that are **quantitative**.

Put a box around any that are **qualitative**.

Explain how you made these decisions.

1. One student recorded: “Sixteen students were present for attendance, and five other students arrived afterward.”

2. Another student recorded: “Half the class was late.”

3. A third student recorded: “The friendliest people were there first.”

4. One visitor to the classroom wrote: “The classroom walls are yellow.”

5. Another visitor noted: “The teacher’s desk is about as long as an adult’s bicycle.”

6. A third visitor wrote: “The chalkboard is 1 m high and 2 m wide.”

Process Skills: Inferring

Making an inference, or inferring, is explaining or interpreting an observation or statement. Have you ever come home, smelled fish cooking, and thought, “We’re having fish for dinner?” You made an observation using your sense of smell and used past experience to conclude what your next meal would be. Such a conclusion is called an inference. Inferences can be reasonable (logical) or unreasonable. A *reasonable inference* is one that makes sense, given what a person knows about the topic. One way to make an *unreasonable inference* is to conclude too much from the evidence.

Hints for Inferring

- **Base your inference on accurate qualitative or quantitative observations.**
- **Combine your observations with knowledge or experience to make an inference.**
- **Try to make more than one logical inference from the same observation.**
- **Evaluate the inferences. Decide what new information you need to show whether your inferences are true. If necessary, gather more information.**
- **Be prepared to modify, reject, or revise your inferences. A reasonable inference should make sense with everything else you know.**

Practise Your Inferring Skills

Suppose you are hiking on the prairie. You use binoculars and see a scene in which a few pronghorn antelope are standing near a herd of cattle. Some people in your group make the following observations and inferences. Which inferences are reasonable?

<u>Observation:</u> <u>The cattle and the antelope are standing quietly together.</u>
1. Inference: The cattle and antelope do not attack each other.
2. Inference: None of the animals in this region attack each other.

<u>Observation:</u> <u>Some of the cattle are eating grass.</u>
3. Inference: The grass is food for the cattle and antelope.
4. Inference: Most of the grass in this area is eaten by the cattle.

<u>Observation:</u> <u>The antelope are looking around.</u>
5. Inference: The antelope are watching for predators.
6. Inference: The antelope can see you.

Designing Experiments Skills: Asking Questions Related to Scientific Inquiry

Asking questions is an essential part of science. Scientific questions can be answered by observations or evidence. This is an important difference from other types of questions.

Hints for Asking Questions Related to Scientific Inquiry

- **Start by making a list of several questions related to the natural world.**
- **Review your list. If any questions cannot be answered by gathering evidence, delete them.**
- **If your questions are general, break them down into questions that can be investigated one at a time.**
- **Good questions that can be answered by scientific inquiry begin with:**
  "What is the relationship between …?"
  "What factors cause …?"
  "What is the effect …?"
- **Your questions should identify a relationship or factor you can investigate.**

Practice Your Questioning Skills

Directions: Read each statement below and indicate if it can be investigated scientifically or not. For statements that can be investigated, write a scientific question you would try to answer.

1. Animals at the top of the food chain eat plants and animals at the bottom of the food chain.

2. Eating too much junk food is bad for you.

3. Wayne Gretzky was the best hockey player ever.

4. When you hear thunder, lightning and rain are soon to follow.

5. Reducing energy consumption is a good thing.

6. Bears hibernate through the winter.

7. A red sunrise means the weather will change.

8. Sunlight is made of seven colours.

9. Structures made of concrete are more stable than structures made of wood.

10. Horoscopes correctly predict your future.

Designing Experiments Skills:
Developing Hypotheses

An hypothesis (plural: hypotheses) is a prediction about the outcome of a scientific investigation. Like all predictions, hypotheses are based on a person's observations and previous knowledge or experience. In science, hypotheses must be testable. That means that researchers should be able to carry out an investigation and obtain evidence that shows whether the hypothesis is true or false.

Hints for Developing Hypotheses

- **Ideas for hypotheses often result from problems that have been identified or questions that have been raised. To help develop ideas for your hypothesis, write down several questions about the topic. Try to narrow the questions to one that can be investigated scientifically. Then write the hypothesis.**
- **Make sure the hypothesis is a prediction.**
- **Make sure the hypothesis can be tested through observations.**
- **Check the way you worded the hypothesis. A properly worded hypothesis should take the form of an *If…then…* statement.**

Practice Your Hypothesizing Skills

1. Read the following hypotheses. Put a check mark beside those containing testable predictions. Circle any hypothesis that is not properly worded, then rewrite that hypothesis.
- If I give my plants fertilizer, then they will grow as big as my neighbour's plants.
- If I get lucky, then my plants will grow bigger.
- My plants aren't growing bigger because I don't water them enough.

2. Write a properly worded hypothesis based on this question: "Will empty trucks use the same amount of gasoline as heavily loaded trucks?"

3. Teachers often mention that good study habits will help improve any student's performance on a test. What are these habits? How could you find out the best ones for you to use? Find out about different study habits. Write a properly worded hypothesis for each habit that will help you find out which ones could help you in class.

Designing Experiments Skills: Controlling Variables

Every experiment involves several variables, or factors that can change. For example, consider this question: Will house plants grow faster if you make the room warmer? To answer this question, you decide to grow plants at different temperatures. The variable that you purposely change and test—the temperature of the room—is called the manipulated variable. The factor that may change as a result of the *manipulated variable*—how fast the plants grow—is called the *responding variable*. An experimental plan is not complete unless the experimenter controls all other variables. Controlling variables means keeping all conditions the same except for the manipulated variable. In an experiment on temperature and plant growth, for example, you have to control any other variables that might affect the growth rate. Such variables include the size of the container, the type of soil, the amount of water, the amount of light, and the use of fertilizer. In addition, you would need to use identical plants in the experiment.

Hints for Controlling Variables

- ▶ **Start by describing the question or process being investigated. Then, identify the manipulated variable and the responding variable in the investigation. Predict the kinds of results you might observe in the responding variable.**
- ▶ **Create a list of all of the other variables that might affect the responding variable.**
- ▶ **Consider whether you have forgotten any of the most common types of variables: time, temperature, length, width, height, mass, volume, number, and the kinds of substances being used in the experiment.**
- ▶ **Determine whether or not one of the objects or groups of objects will serve as the control.**

Practice Your Skills at Controlling Variables

1. You are planning an experiment to find out whether the rate at which water freezes depends on the shape of its container. Identify the manipulated variable and the responding variable. List the other variables you would control.

2. Researchers want to determine the best temperature for storing batteries. Describe a possible experiment and list the variables in that experiment. Identify which are the manipulated and the responding variables.

3. Your friend has to plan an experiment for a science fair. He asks for your help. His topic is "The Strongest Cloth for Backpacks." What variables must his experiment include? What variables must be controlled?

4. Suppose you wanted to compare two different stain removers to learn which one was better at removing food stains from clothing. In your test, what variables would you need to control?

Designing Experiments Skills:
Forming Operational Definitions

Suppose that your class and another class work together on an experiment to determine what kinds of balls roll the fastest. When the experiment is finished, you all want to compare your data, so you must all perform the experiment in the same way. That means that each time a team of students repeats the experiment, they have to use the same materials and procedure as every other team. They must also make their measurements in an identical manner. Scientists also repeat investigations—their own and those of other researchers—to be sure that specific data are reliable. To make such repetition possible, scientists use operational definitions. An *operational definition* is a statement that describes how a particular variable is to be measured, or how an object or condition is to be recognized. Operational definitions tell you what to do or what to observe. (The word “operational” means “describing what to do.”) Operational definitions need to be clear and precise so that a reader knows exactly what to observe or measure.

Hints for Forming Operational Definitions

- **Look over the written plan for carrying out an investigation, or write up a plan.**
- **Identify and list any variables or terms that do not have a single, clear, obvious meaning.**
- **If there are several reasonable ways to make an observation or to perform an action, choose one that suits the purpose of the investigation.**
- **Write a clear, complete definition of what the researcher should do or measure. Check your definition by asking yourself: Will this definition tell another person what to observe or how to measure? If necessary, revise your definition before starting your investigation.**

Practice Your Operational Definitions

Write an operational definition for each of the following. A good operational definition tells a person clearly how to perform an observation or take a measurement. Exchange your definitions with a partner to test if you can each follow the other person’s instructions. Make any changes necessary.

1. On a cold day, let the water in the pan freeze outdoors.

2. You will test these two fertilizers to determine which one helps plants grow faster.

3. Rearrange the list of zoo animals in order of their size, with the biggest ones first.

4. You want to find out which kind of ball rolls fastest.

5. When you finish working on an experiment, wash your hands thoroughly.

Data Analysis: Graphing Data

Graphing is an important way to organize and present results in science. A graph lets you see patterns and trends that are very difficult to spot from a table of numbers. There are several types of graphs you can use, from bar to line to circle, and specialized types of graphs, such as best-fit, line, and scatter plots. Be sure you are comfortable with all of these, because they will be very helpful as you interpret the results of your experiments.

Hints for Graphing Data

- **Start by organizing your data in a table. A table makes it easier for you to construct a graph.**
- **Give your graph a title that identifies the variables or the relationship between the variables in the graph. For example, "Number of Frog Croaks at Different Temperatures" is a complete title that clearly describes a graph.**
- **On graph paper, draw a horizontal, or *x*-, axis and a vertical, or *y*-, axis.**
- **Label the *x*-axis with the name of the manipulated variable (what you are studying). Label the *y*-axis with the name of the responding variable (measurements you have made). Include the units of measure.**
- **Determine the scale for the measurements to be shown on the vertical axis. Choose a scale that lets you represent all the values in your data table on the same page. Each square on the graph paper will represent a certain amount. All squares have the same value.**
- **If making a bar graph: on the *x*-axis, show a bar for each category being represented. Using your data, draw in the bars. Remember, all the bars must be the same width. Use an equal number of squares for the width of each bar and leave a space of at least one square between the bars.**
- **If making a line graph: plot each point where the variables intersect. You can do this by following an imaginary line up from the measurement on the *x*-axis. Then follow a second imaginary line across from the corresponding measurement on the *y*-axis. Place a dot where the two lines intersect.**
- **Consider whether you will plot from point to point or make a best-fit graph. If you plot from point to point, each segment connecting two adjacent points should be straight. If you make a best-fit graph, the connecting line should be smooth.**

Practice Your Graphing Skills

Make your own personal reminder sheet about graphs. Include an example of each type, with labels. Make notes about when you would use each type. Add any helpful tips you learn.
Keep your sheet handy until you are confident about graphing data.

Data Analysis: Interpreting Data

When you are doing a scientific inquiry, you make observations and measurements. These recorded values are called your *data*. Once your data is collected, you need to interpret it. Interpreting data means looking for a pattern or trend. One way to find patterns is by graphing your data. By analyzing your graph, you can determine if a pattern exists. Comparing your interpretation to something you already know will help you figure out if you have made a logical interpretation.

Hints for Interpreting Data

- **Organize your data into a table or arrange your data in some type of order.**
- **Make a graph for your data.**
- **Review your graph for patterns or trends.**
- **Using your data, infer what you think may be happening and compare your inferences with what you already know or have researched.**

Practice Your Interpreting Skills

One way to increase your interpreting skills is to think about the patterns shown on graphs instead of the data itself. Here's how. Sketch a graph to show each of the following patterns. You won't be able to put in actual data, but you can label the axes and give the graph a title. You will also be able to draw in a line to show what is happening.

1. The height of a corn plant increases with time.

2. The number of clean cars on the road is lowest in the winter months.

3. A volume of water set over a heat source will gradually decrease.

4. The number of cats found in an area increases just after the number of mice increases. The number of cats decreases after the number of mice decreases. This continues every year for ten years. (Hint: You may need two lines on the same graph.)

5. A student measured her height once a month for two years. Her height increased for four months, then remained the same.

6. The processing speed of computer chips is increasing far more quickly than anyone had predicted. This trend shows no sign of slowing down.

7. Using a bar graph, show a comparison between: (a) the approximate number of hours a week you spend on homework now and (b) the number of hours a week you predict you will be spending on homework next year.

Data Analysis: Answers to Skills Worksheets

Observing

1. accurate; objective; quantitative
2. inaccurate, objective; quantitative (if we know the total number of students)
3. inaccurate, not objective, qualitative
4. accurate; objective; qualitative
5. inaccurate (but useful); objective; quantitative (a reasonable estimate based on a standard)
6. accurate; objective; quantitative

Measuring

1. juice – cylinder; volume; mL box – centimetre ruler; close in size to object; cm table – metre ruler; close in size to object; m load – balance; mass; kg
2. Answers will vary. Watch for decimal places and units. To compare to leg: centimetres; to compare to floor: metres.
3. Methods and answers will vary.

Classifying

Answers will vary. Encourage students to try several systems to form their groupings until they find one that helps them answer the questions most readily.

Inferring

1. reasonable
2. unreasonable, because you have no evidence about any other animals
3. reasonable
4. unreasonable, because you have no evidence about the amounts eaten
5. reasonable
6. reasonable

Predicting

Answers will vary.

Asking Questions Related to Scientific Inquiry

1. Yes. Sample question: What living things are in the diet of a hawk?
2. Yes. Sample question: What is the relationship between good health and the amount of "junk food" consumed?
3. No. Although it could be argued that the analysis of statistics could be used to support the statement. The criteria for "best" are likely too variable.
4. Yes. Sample question: How frequently is the sound of thunder followed by lighting and rain within 30 min?
5. No. Unless the term "good thing" is more closely defined.

continued ➡

6. Yes. Sample question: What environmental conditions cause bears to hibernate?

7. Yes. Sample question: What is the relationship between the appearance of a red sunrise and the occurrence of changing weather that day?

8. Yes. Sample question: What are the components of visible sunlight?

9. Yes. Sample question: Which will be more stable of two identical structures, one of wood or one of concrete?

10. No. Unless the horoscope prediction is something that can be measured and verified.

Developing Hypotheses

1. testable; not testable (luck can't be measured); testable but rewrite as: If I water my plants regularly, they will grow bigger than plants I do not water regularly.

Controlling Variables

1. mv: container shape; rv: time until water freezes; other variables should include: volume of water, initial temperature of the water, temperature outside the container, composition of container.

2. Answers will vary. mv: storage temperature, rv: charge left in battery after storage; variables to be controlled: time in storage, initial charge in batteries, method of testing charge, how batteries are handled.

3. mv: mass or load used to test cloth strength, rv: time until cloth rips; variables to be controlled: method of testing, treatment of cloth samples, size of cloth samples.

4. mv: various food stains, rv: amount of stain removal; variables to be controlled: type of fabric, amount and preparation of staining material, amount of stain remover used, time allowed for stain remover to act on stain.

Forming Operational Definitions

Answers will vary. Emphasize the importance of clear communication. Pair up students who have done different statements and ask them to follow each other's directions.

Graphing Data

Students may feel they have a good understanding of when and how to use graphs, but often fail to remember important details when the next opportunity to graph data arises. A study sheet is a way to empower the student's own learning and to reassure them that they will have the information they need at hand in the future.

Interpreting Data

Model one of these examples for students if you wish. They are sometimes loath to make a sketch of a graph, but this is an excellent tool to help them make the connection between what a graph shows and what it means. Emphasize the identification of variables and units, as well as shape. #6 will be difficult if students haven't encountered geometric increase. Omit if desired.