The Scientific Method
Exploring Experimental Design

Unit Overview

PURPOSE
Through this series of activities you will identify and apply the steps of the scientific method.

MATERIALS

Come Fly With Us
Penny Lab
Scientific Method Practice 1
Scientific Method Practice 2

PROCEDURE

Day 1

1. Take notes as your teacher discusses the steps of the scientific method.

2. Do the *Come Fly With Us* activity in class. Turn it in at the end of the period.

3. Do the *Scientific Method Practice 1* activity for homework. Be ready to turn in the write-up at the beginning of the next period.

Day 2

1. Turn in *Scientific Method Practice 1* to your teacher at the beginning of class. Your teacher will review the correct answers.

2. Begin the *Penny Lab* after collecting your materials.

3. Turn in the *Penny Lab* write-up to your teacher after completing it.

4. Do the *Scientific Method Practice 2* activity for homework. Be ready to turn in the write-up at the beginning of the next period.

Day 3

1. Turn in *Scientific Method Practice 2* to your teacher at the beginning of class. Your teacher will review the correct answers.

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Come Fly With Us

This assignment is intended to be a quick and easy guide to the methods scientists use to solve problems. It should also give you information about how to “wing your way” through your own experiments. You are going to start by making a model helicopter with the attached instructions. You will be given a problem question, and it is your job to write a suitable hypothesis. Remember, your hypothesis should be a possible answer to the problem question and it should be based upon what you already know about a topic.

GLOSSARY OF WORDS USED IN CONDUCTING EXPERIMENTS

- **problem**: scientific question that can be answered by experimentation
- **hypothesis**: an educated prediction about how the independent variable will affect the dependent variable stated in a way that is testable (This should be an “If…then…” statement.)
- **variable**: a factor in an experiment that changes or could be changed
- **independent variable**: the variable that is changed on purpose
- **dependent variable**: the variable that responds to the independent variable
- **control**: the standard for comparison in an experiment; the independent variable is not applied to the control group
- **constant**: a factor in an experiment that is kept the same in all trials
- **repeated trials**: the number of times an experiment is repeated

PURPOSE

In this assignment you will practice applying the steps of the scientific method.

MATERIALS

copy of helicopter model
scissors
pen or pencil

PROCEDURE

1. Find the section labeled Hypothesis on your student answer page. Read the problem question and respond with an appropriate hypothesis. Remember to use an "If…then…" format.

2. Once you have made your hypothesis, you should test it for accuracy. Cut out and fold the helicopter following the directions on the bottom of the helicopter page.

3. Stand on a chair and hold your helicopter by the top of the "T" at shoulder level.

4. Drop the helicopter and note whether it spins clockwise or counterclockwise. Repeat this test several times.

5. Refold the blades so that the square on section Y shows when you look down on top of the helicopter.

6. Stand on a chair and hold your helicopter by the top of the "T" at shoulder level. Drop the helicopter and note whether it spins clockwise or counterclockwise.

7. Repeat this test several times.

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Come Fly With Us

PROBLEM

How will changing the direction that the paper helicopter blades are folded affect the "flight" of the helicopter?

HYPOTHESIS

ANALYSIS

You have just performed an experiment. Experiments involve changing something to see what happens. In this case, you refolded the helicopter blades. You made this change on purpose to learn about its effect on the flight of the helicopter. The parts of an experiment that change are called *variables*.

When designing an experiment, you should choose one variable that you will purposely change. You will measure the effect of this *independent variable* on another variable that you think will respond to the change. The responding variable is called the *dependent variable*.

If you kept every variable except the folds the same in each test, you were making it a fair test. Why? Only the variable you changed could be causing the dependent variable to change because everything else was kept constant.

To have a fair test, you also need a *control*, or a standard for comparison. A control for the helicopter experiment would be an "unchanged" helicopter against which you could compare the results. Your control is the helicopter before the blade directions are changed. After the blades have been flipped, you then have your experimental helicopter.

It is important to note that in some experiments, it is impossible to have a control that is completely unchanged. For example, let's say you are trying to determine the effect of light from different light sources on plant growth. The control plant needs some kind of light in order to live through the experiment. So, you have to choose one light source—possibly normal sunlight—to be the standard of comparison.

After you refolded the blades of the helicopter, you dropped the helicopter several times and observed the results. These repeated trials enable you to be more confident of your results. If you conducted your experiment only once, the results could be due to an error or a chance event, such as a draft. But, when you repeat your experiment many times and each time achieve similar results, you can be more confident that your findings are not due to an error or chance.

Complete the following conclusion questions using complete sentences.

CONCLUSION QUESTIONS

1. In the helicopter experiment, what was the independent variable?

2. What was the dependent variable?

3. List three things you should try to keep constant each time you try this experiment.

Read the following paragraph and answer # 4–10:

> Bonita wanted to know if adding mass to her paper helicopter would affect how long it would stay in the air. She predicted that adding some mass would help to stabilize the helicopter and keep it in the air longer than a helicopter without extra mass. She experimented with different numbers of paper clips attached to her helicopter.

4. What is the problem question in Bonita’s experiment?

5. What is Bonita’s hypothesis?

6. What is her independent variable?

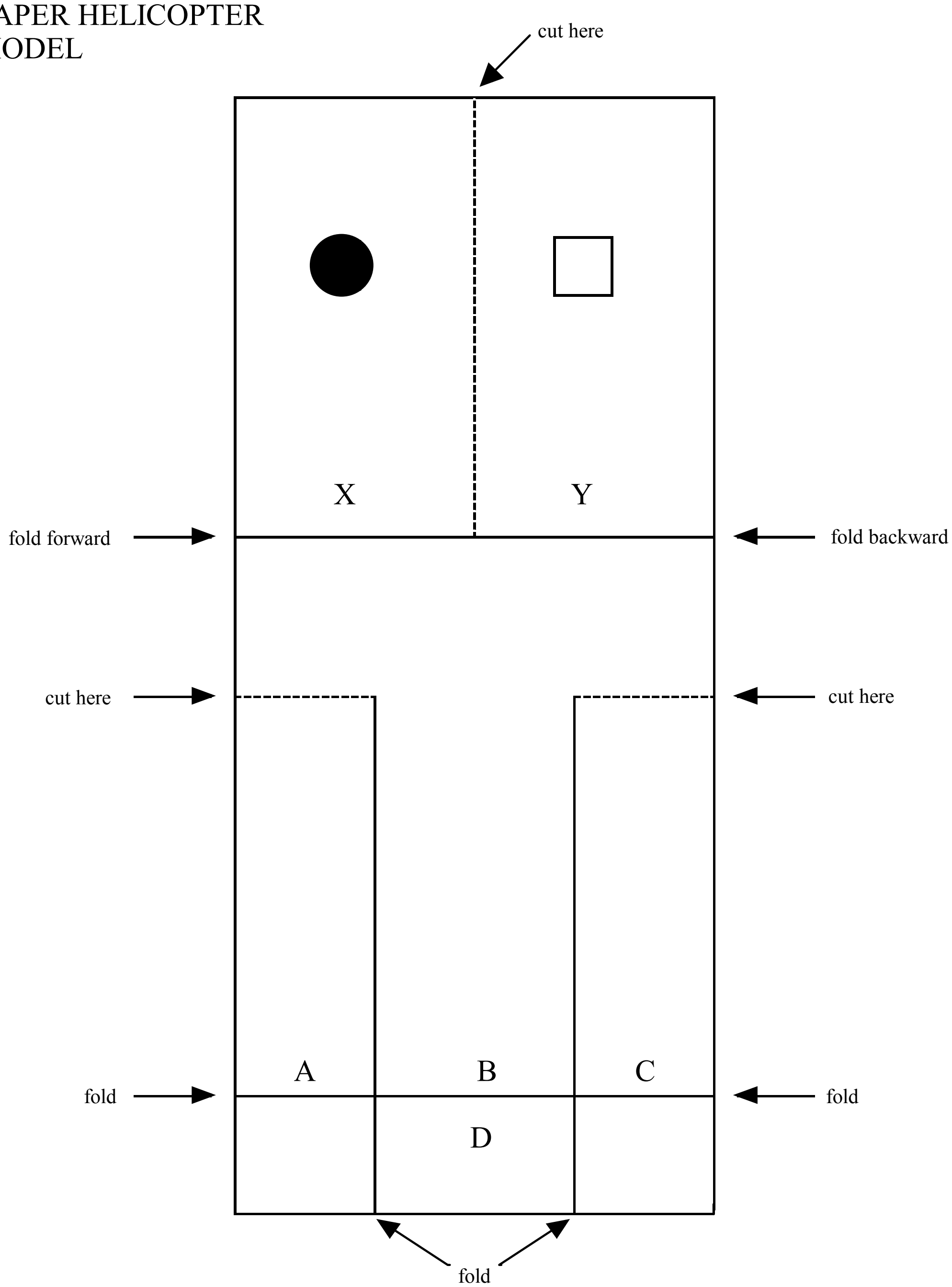
7. What is her dependent variable?

8. What should her constants be?

9. What can she use for a control?

10. Why should Bonita retest her experiment between 5–10 times?

PAPER HELICOPTER
MODEL



INSTRUCTIONS:
1. Cut out the rectangular helicopter (above).
2. Now cut along dotted lines.
3. Fold along the solid lines: section C behind section B, section A behind section B, and section D behind section B.
4. Complete the helicopter by folding blade X with the dot up and blade Y in the opposite direction with the square down.

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Scientific Method Practice 1

DIRECTIONS: *Read the following paragraphs and then answer the questions that follow on a separate sheet of paper. Use complete sentences to answer all questions. Be sure to restate the question in your answer.*

Science differs from other subject areas in the way it seeks to answer questions. This approach to problem solving is called the scientific method. The scientific method is a systematic approach to problem solving. Listed below are the basic steps of the scientific method, in one possible order:

- Stating the problem
- Gathering information on the problem
- Forming a hypothesis
- Performing experiments to test the hypothesis
- Recording and analyzing data
- Stating a conclusion
- Repeating the work

Erika baked a cake for her mother's birthday. When the cake was taken from the oven, Erika noticed that the cake had not risen. She guessed that the oven had not heated to the correct temperature. She set up the following experiment to test her hypothesis.

First, Erika put a thermometer in the oven. She then turned the oven dial to 375ºF. She noticed that the preheating light came on when she turned the oven on. She waited until the preheating light went out, indicating that the oven was up to the specified temperature. Erika then read the thermometer inside the oven. It read 375ºF. Erika concluded that the oven was heating properly.

CONCLUSION QUESTIONS

1. What was Erika's problem? [The problem should be stated as a question.]

2. What was Erika's hypothesis? [This is an answer to your problem question.]

3. What was Erika's conclusion? [This states whether your hypothesis was supported.]

4. Which step in the scientific method do you think Erika should do next? Explain your reasoning.

5. List two other hypotheses which might explain why the cake did not rise.

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Penny Lab

PURPOSE
In this activity you will learn about controls and variables in an experiment. You will also learn what constitutes a valid experimental procedure.

MATERIALS

penny	calculator (optional)
dropper or pipet	graph paper and notebook paper
water	ruler
paper towel	pen or pencil

DEFINITIONS
- **variable**: aspects of an experiment that change or could be changed
- **independent variable**: variable that is changed on purpose
- **dependent variable**: variable that responds to the independent variable
- **constant**: aspects of an experiment that are kept the same in all trials

PROCEDURE

1. Answer each of the following questions using complete sentences. For fill-in-the blank statements, copy the entire sentence.

2. Copy the lab purpose onto your paper.

3. Your task is to guess how many drops of water will fit on the "Lincoln" side of a penny.

   [Copy the following statement.] PROBLEM: How many drops of water will fit onto the "Lincoln" side of a penny?

4. [Copy the following statement and make a prediction by filling in the blank.] HYPOTHESIS: I predict that _________ drops of water will fit on the head side of a penny.

5. After you have made your hypothesis and have written it down on your lab paper, you will write it on the chalkboard under the heading "Predicted Number of Drops."

6. Copy the following chart onto your paper. Be neat and use a ruler!

TEST RESULTS:

	Trial #1	Trial #2	Trial #3	Actual Average
Number of Water Drops	______	______	______	______

7. Test to see if your hypothesis is correct. Place your penny on a paper towel and, using the dropper, add water to the "Lincoln" side of the penny, one drop at a time, counting each drop until the water spills over. Do not count the drop that causes the water to spill over. Write the number of drops you counted under Trial #1 on your chart. Repeat this procedure two more times. Fill in the number of drops you count for each trial under the appropriate heading on your Test Results chart.

8. Find the average of your three trials, round your answer to a whole number (no decimals), and write the average number of drops on your Test Results chart. Then write your average on the chalkboard under the heading "Actual Average".

9. Write a sentence that will serve as your conclusion for this experiment. Remember that your conclusion should state whether your hypothesis was supported.

10. Make a bar graph of the class results using the data from the "Actual Average" row. The x-axis (horizontal line) should be titled "Average Number of Drops" and the y-axis (vertical line) should be titled "Number of Tests." You will be graphing the total number of people in your class that got an average within a range of numbers. For example, if 5 people got an average between 0 and 10, you would graph this data as your first bar. The next bar would be for all of those who got an average between 11 and 20 drops. Before graphing, you will need to organize the class data into ranges—make a chart that shows how many people got averages between 0–10, 11–20, 21–30, etc. When you have finished your bar graph, give it an appropriate title.

11. Answer the conclusion questions on your paper. Be sure to use complete sentences.

CONCLUSION QUESTIONS

1. Using your bar graph, determine if the average number of drops for each experimenter is about the same.

2. List four reasons why the actual number of drops for each experimenter was similar or dissimilar.

3. Are the results of this experiment "valid"? Why or why not? Be sure to think about what makes an experiment valid.

4. In this experiment, there were a limited number of constants. Name two of them.

5. What was the independent variable in this experiment?

6. What was the dependent variable in this experiment?

7. Is it possible to state definitively how many drops of water will fit on the "Lincoln" side of a penny with this lab procedure? Why or why not?

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Scientific Method Practice 2

DIRECTIONS: *Answer these questions on a separate sheet of paper using a black or dark blue ink pen. Use complete sentences to answer all questions. Be sure to restate the question in your answer!*

Stephanie and Amy were vacationing in Canada. Bundled up in warm clothing, they walked along the beach. Glistening strips of ice hung from the roofs of the beach houses. Only yesterday, Stephanie commented, these beautiful icicles had been a mass of melting snow. Throughout the night, the melted snow had continued to drip, freezing into lovely shapes. Near the ocean's edge, Amy spied a small pool of sea water. Surprisingly, she observed the sea water was not frozen like the icicles on the roofs. What could be the reason, they wondered?

A scientist might begin to solve the problem by gathering information. The scientist would first find out how the sea water in the pool differs from the fresh water on the roof. This information might include the following facts: The pool of sea water rests on sand, while the fresh water drips along a tar roof. The sea water is exposed to the cold air for less time than the fresh water. The sea water is saltier than the fresh water.

Using all of the information that has been gathered, the scientist might be prepared to suggest a possible solution to the problem. A proposed explanation or solution to a scientific problem is called a hypothesis. A hypothesis almost always follows the gathering of information about a problem. Sometimes, however, a hypothesis is a sudden idea that springs from a new and original way of looking at a problem.

A scientist (or a science student) does not stop once a hypothesis has been suggested. In science, evidence that either supports a hypothesis or does not support it must be found. This means that a hypothesis must be tested to show whether it is supported. Such testing is usually done by performing experiments.

Experiments are performed according to specific rules. By following these rules, scientists can be confident that the evidence they uncover will clearly support or not support their hypothesis. For the problem of the sea water and freshwater, a scientist would have to design an experiment that ruled out every factor but salt as the cause of the different freezing temperatures. Stephanie and Amy, being excellent science students, set up their experiment in the following manner.

First, they put equal amounts of fresh water into two identical containers. Then Stephanie added salt to only one of the containers. [The salt is the independent variable. In any experiment, only one independent variable should be tested at a time. In this way, scientists can be fairly certain that the

results of the experiment are caused by one and only one factor—in this case the variable of salt.]
To eliminate the possibility of hidden or unknown variables, Stephanie and Amy conducted a controlled experiment. A control group is set up exactly like the one that contains the variable. The only difference is that the control setup does not contain the independent variable. Scientists compare the results of the experimental setup to the control setup.

In the experiment, Stephanie and Amy used two containers of the same size with equal amounts of water. The water in both containers was at the same starting temperature. The containers were placed side by side in the freezing compartment of a refrigerator and checked every five minutes. But only one container had salt in it. In this way, they could be fairly sure that any differences that occurred in the |two containers were due to the single variable of salt. In such experiments, the part of the experiment with the salt is called the experimental setup. The part of the experiment without salt is called the control setup.

Stephanie and Amy collected the following data: the time intervals at which the containers were observed, the temperature of the water at each interval, and whether the water in either container was frozen or not. They recorded the data in the tables below and then graphed their results.

WATER (control setup)

Time (min)	0	5	10	15	20	25	30
Temperature (ºC)	25	20	15	10	5	0*	–10

WATER WITH SALT (experimental setup)

Time (min)	0	5	10	15	20	25	30
Temperature (ºC)	25	20	15	10	5	0	–10*

*Asterisk means liquid has frozen

Stephanie and Amy might be satisfied with their conclusion after just one trial. For a scientist, however, the results from a single trial are not enough to reach a conclusion. A scientist would want to repeat the experiment many times to be sure the data was reproducible. In other words, a scientific experiment must be able to be repeated. Also, before the conclusion of a scientist can be accepted by the scientific community, other scientists must repeat the experiment and check the results. Consequently, when a scientist writes a report on his or her experiment, that report must be detailed enough so that scientists throughout the world can repeat the experiment for themselves. In most cases, it is only when an experiment has been repeated by scientists worldwide that it is considered to be accurate and worthy of being accepted.

By now it might seem as if science is a fairly predictable way of studying the world. After all, you state a problem, gather information, form a hypothesis, run an experiment, and determine a conclusion. However, sometimes it isn't so neat and tidy.

In practice, scientists do not always follow all the steps in the scientific method. Nor do the steps always follow the same order. For example, while doing an experiment a scientist might observe something unusual or unexpected. That unexpected event might cause the scientist to discard the original hypothesis and suggest a new one. In this case, the writing of the hypothesis actually followed the experiment.

As you already learned, a good rule to follow is that all experiments should have only one variable. Sometimes, however, scientists conduct experiments with several variables. Naturally, the data in such experiments are much more difficult to analyze. For example, suppose scientists want to study lions in their natural environment in Africa. It is not likely they will be able to eliminate all the variables in the environment and concentrate on just a single lion. So, although a single variable is a good rule and you will follow this rule in almost all of the experiments you design or perform, it is not always practical in the real world.

There is yet another step in the scientific method that cannot always be followed. Believe it or not, many scientists search for the truths of nature without ever performing experiments. Sometimes the best they can rely on are observations and natural curiosity. Here is an example. Charles Darwin is considered the father of the theory of evolution, how living things change over time. Much of what we know about evolution is based on Darwin's work. Yet Darwin did not perform a single controlled evolutionary experiment! He based his hypotheses and theories on his observations of the natural world. Certainly it would have been better had Darwin performed experiments to prove his theory of evolution. But as the process of evolution generally takes thousands, even millions of years, performing an experiment would be a bit too time consuming.

CONCLUSION QUESTIONS

1. State Stephanie and Amy's problem in the form of a question.

2. Form a hypothesis to answer the problem question above based on the fact that fresh water does not contain salt.

3. According to the data table above, at what temperature did the experiment begin?

4. At what time intervals were the temperature measurements taken?

5. What conclusions can you draw from these graphs about the effect of salt on the freezing point of water?

6. What can you say about the rate at which the temperature in the fresh water container dropped compared to the rate at which the temperature in the salt water container dropped?

7. What was the independent variable in Stephanie and Amy's experiment?

8. What was the dependent variable?

9. Explain why detailed, step-by-step written procedures are an essential part of any scientific experiment.

10. The following hypothesis is suggested to you: Water will heat up faster when placed under the direct rays of the sun than when placed under indirect, or angled, rays of the sun. Design an experiment to test this hypothesis. Be sure to number each step of your procedure. Identify your independent variable, dependent variable and control. Identify those things which will remain constant during your experiment.