



1. SCIENTIFIC METHOD

Using the Scientific Method to Investigate Gum

INTRODUCTION

One of the goals of science is to come up with explanations about how the natural world (all the things we see or experience) functions. Although there are other systems for understanding and explaining the world around us (such as religion and traditional beliefs) science differs from these in that scientific explanations are based on laws of nature. Laws of nature are patterns in nature that are objective (do not depend on faith, authority, or opinion), are testable (can be demonstrated with experiments), and are consistent (the same conditions produce the same results).

A. THE SCIENTIFIC METHOD

To learn about the natural world, scientists use a four step procedure called the scientific method. The four steps of the scientific method are listed below. To help illustrate the scientific method, an example that a botanist (a biologist who specializes in plants) might use is given in *italics* below each step.

1 **Observe something in the natural world and ask a question about how it works.** The part of the natural world that is observed and investigated is usually the area that the scientist specializes in. A botanist, for example, would observe and ask a question about how plants function.

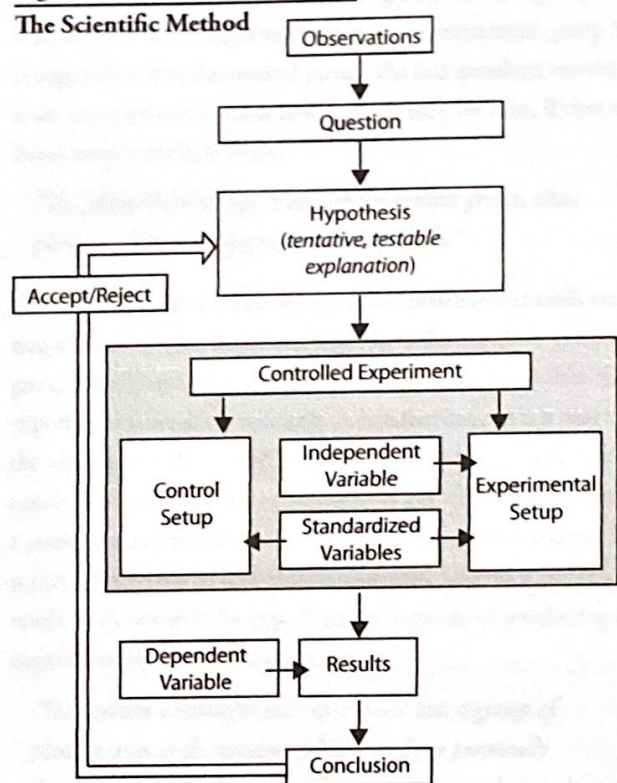
"Manure has traditionally been used as a fertilizer (something added to the soil that make the plants grow bigger). Some people use food scraps as fertilizers. What sorts of food scraps can be used as fertilizers?"

2 **Make a hypothesis (an educated guess) which attempts to answer the question.**

"Egg shells put into the soil will act as a fertilizer"

Figure 1.1

The Scientific Method



3 **Design and carry out an experiment that is capable of testing the hypothesis.** In other words, the experiment must be designed so that it will produce results that either clearly support or clearly falsify (disprove) the hypothesis. It helps to use "If-Then" predictions based on your hypothesis.

"Grow 100 plants with egg shells added to the soil. Also grow 100 plants with no egg shells added to the soil. If the hypothesis is correct, then the plants with egg shells will grow taller than the plants without eggs shells. If the hypothesis is incorrect, then the plants with egg shells will not grow any taller than the plants without eggs shells"

4 **Reject the hypothesis if the results are not consistent with the hypothesis or accept the hypothesis as possibly true if the results are consistent with the hypothesis.** Notice that the hypothesis is not "proven to



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be true" even if the results do support it. This is because there may be explanations other than the hypothesis for the experimental result. For example, if the plants with egg shells do grow taller, it may be that pushing the egg shells into the soil added air to the soil, and that the air (not the egg shells) is what helped the plants grow.

B. DESIGNING A GOOD EXPERIMENT

The most challenging part of the scientific method is usually the third step, designing and carrying out an experiment to test the hypothesis. A well-designed experiment should include all of the following characteristics:

1 An independent variable. The independent variable is the part of the experiment that the scientist changes or manipulates to see what effect occurs.

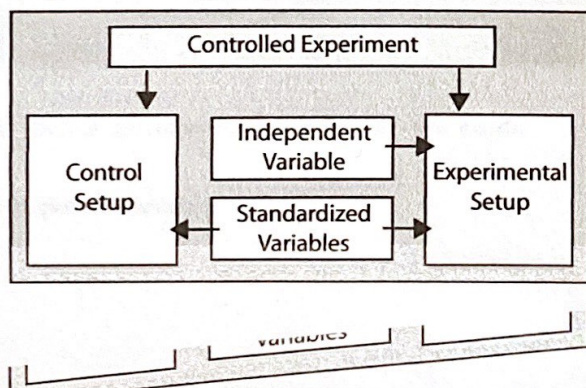
"The fertilizer is the independent variable, since that is what the experiment changes to see its effect."

2 A dependent variable. The dependent variable is the part of the experiment that changes because of the change in the independent variable. In other words, the dependent variable is the effect that occurs from changing the independent variable.

"The size of the plants is the dependent variable, since the size is expected to change because of the fertilizer in the soil."

3 An experimental group. The experimental group is the group of subjects where the independent variable is set to an unusual or test level.

Figure 1.2
Experiment Design



"The plants grown with egg shells are the experimental group, since the ability of egg shells to fertilize the soil is what is being tested"

4 A control group. A control group is the group of subjects in the experiment that the experimental group is compared to. For the control group, the independent variable is set to a normal or usual level (which may be zero, if that is considered a normal level).

"The plants with no egg shells are the control group, since plants are not usually grown with egg shells."

Some experiments include things called **positive controls** and **negative controls**. These are slightly different than control groups. Positive and negative controls serve to show that the experiment is working correctly. A positive control is a part of the experiment that is deliberately designed to give a positive result. It shows that the experiment is capable of producing a positive result when it is supposed to. A negative control is a part of the experiment that is designed to give a negative result. It shows that the experiment is capable of producing a negative result when it is supposed to.

"The positive control for the experiment was a group of plants grown with manure, which has been previously shown to increase plant size. The negative control was plants grown with plastic added to the soil. Plastic has previously been shown to have no effect on plant growth."

5 The experiment should contain repetition. This means that there should be more than one subject in the experimental group and the control group. Why? In general, the more repetition, the less likely that your results are due to random chance.

"The experimental group and the control group each contained 100 plants."

6 The experiment should be well defined. One aspect of "well defined" is that the procedure (the steps) must be written down and clearly described. The true test of a well written experimental procedure is that another scientist could duplicate it exactly using just the written directions. Another aspect of "well defined" is that everything in the experiment, aspect of "well defined" is that everything in the experiment,

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such as the materials, chemicals, equipment, environmental conditions, and the subjects (the organisms involved in the experiment), should be described as exactly as possible. All of the factors that are kept equal in the experiment and control groups are called **standardized variables**. Another aspect of "well defined" is that all parts of the experiment should be quantified. This means they should be measured by numbers.

a) All seeds in this experiment are of the plant species. All seeds were planted 4 cm deep in 10 cm of soil obtained from Central and Davis roads in Salinas, California. All plants were grown in plastic containers at 30° C temperature and watered with 50 ml of purified water once each day at 10:00 a.m. All plants received artificial sunlight from a 100 watt full-spectrum bulb for 16 hours per day.

b) One group of 100 seeds (the experimental group) had egg shells added to the soil at the time of planting. Each seed had 5 grams of egg shell fragments added to its soil.

c) One group of 100 seeds (the control group) had no egg shells or any other kind of fertilizer added to the soil.

d) The positive control for the experiment was a group of 10 plants, each grown with 5 grams of commercial manure (which has been previously shown to increase plant size). The negative control was a group of 10 plants grown with 5 grams of plastic added to the soil of each plant. Plastic has previously been shown to have no effect on plant growth.

e) After 10 days of growth, the length of each plant. The length measurement was the distance from the tip of the plant's highest leaf to the soil.

REVIEW QUESTIONS

1. Define the following terms in your own words.

Independent variable:

Dependent variable:

Experimental group:

Control group:

Standardized variables:

C. APPLYING THE SCIENTIFIC METHOD TO THE STUDY OF GUM

For today's exercise, your group will devise and conduct an experiment on gum using the scientific method.

1. DEVISING A HYPOTHESIS

First, your group should devise a hypothesis about gum. The hypothesis can be anything, as long as it relates to gum. Try to make it as imaginative and unique as possible. Write your experimental design on page 1-5 (Hypothesis, dependent variable, independent variable, experimental group, and control group) and bring it to your instructor for approval.

To give you some starting ideas, here are some experiments that other groups have tried:

- The effect of time in the freezer on the gum's hardness
- The effects of gum type on bubble size or stretch length
- The effects of chewing time on the gum's hardness or stretch length
- The effects of boiling gum in detergent, salt, or sugar water
- The effects of chew time on the gum's weight
- The effect of eating food while chewing gum



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Some of the materials that are available to you:

Bubble gum (sugar and sugarless)
Chewing gum (sugar and sugarless)
Hot plates and beakers
Thermometers
Scales
Salt, sugar, artificial sweetener
Meter sticks
Milk, bread
Razor blades
Freezer/Ice

2. WRITING YOUR EXPERIMENTAL PROCEDURE

Design an experiment to test your hypothesis. Write out the experimental procedure in numbered steps on the bottom half of page 1-5, then bring it to your instructor for approval.

The approval requirements are:

- 1) Your experimental must be well defined.
- 2) Your experimental procedure must be able to produce quantifiable results that clearly support or clearly refute your hypothesis.
- 3) It must include at least three repetitions of each measurement type.

When the instructor has approved your experiment, carry out your the experiment. When you are done with the experiment, write your Results and Conclusions (see next section).

3. WRITING THE RESULTS AND CONCLUSIONS OF YOUR EXPERIMENT

Experimental results: Present all your results in a table, and present the average value of your results in a graph. (You can use the ones on page 1-6 or make your own). Both the table and the graph must be made as follows:

- They must have a title ("table 1" or "graph 1", for example) and a legend (a brief but complete explanation of what data is being presented).
- Each axis, column, and row must state what was measured and in what units.
- On the graph, the independent variable usually goes on the X-axis and the dependent variable goes on the Y-axis.

(Use the example table, graph, and titles, and legends in Figure 1.3 and Figure 1.4 as models for your own). **Show your instructor your results table and graph when done.**

Conclusions: State whether your data support or refute your hypothesis. If your data did support your hypothesis, briefly discuss why your hypothesis is true (for example, why sugar caused smaller bubbles) and if your result explains other non-gum phenomena. If your data did not support your hypothesis, briefly discuss the ways you would modify your hypothesis or what factors might influence the effect you were measuring. **Show your instructor your conclusion when done.**

Figure 1.3

The effect of chewing time on the weight of Bazooka Joe gum.

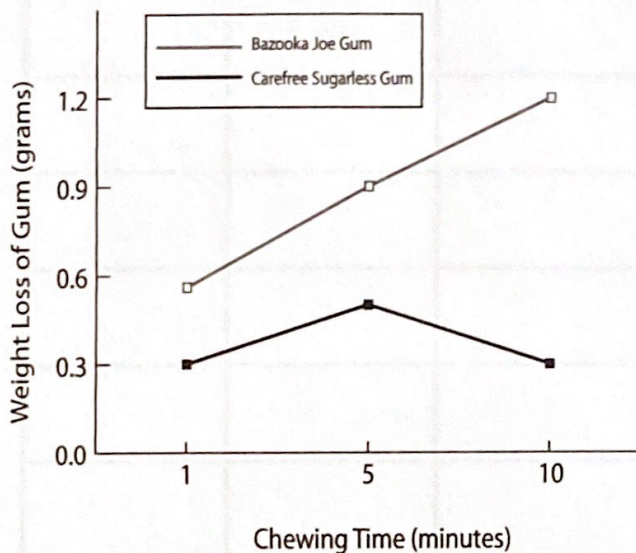
Sample	Chew time (min)	Weight loss (g)
1	1	0.5
2	1	0.7
3	1	0.5
4	5	0.9
5	5	0.7
6	5	1.1
7	10	1.3
8	10	1.2
9	10	1.1

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Figure 1.4

The average weight loss of Bazooka Joe gum and Care-Free sugarless gum at 1 minute, 5 minutes, and 10 minutes chewing time.



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Hypothesis: _____

Independent variable: _____

Dependent variable: _____

Experimental group: _____

Control group: _____

Experimental procedure:

(continue on next page if you need more room)

REVIEW QUESTIONS

1. In Figure 2.3, which column contains the dependent variable?
2. Which column contains the independent variable?
3. Name 2 possible standardized variables in this experiment.



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Table 1.1.

Title:

Conclusion:

Graph 1.1.

Title:
