Scientific Method • Step 5 • Gathering & Evaluating the Data

"Man, unlike any other thing, organic or inorganic in the universe, grows beyond his work, walks up the stairs of his concepts, emerges ahead of his accomplishments."

• John Steinbeck
Author

Objectives of This Section

This is where you bring the bacon home. Taking the data that you collect and connecting it to a logical conclusion is at the very heart of the scientific method.

____ 1. Fill in the data tables you have prepared.

____ 2. Use the data to create graphs that will quickly display the information you have collected.

____ 3. Collect and prepare other forms of data—recordings, photos, drawings, and so on—that will support your hypothesis.

____ 4. Develop descriptions, explanations, predictions, and models using evidence.

____ 5. Think critically and logically to make the relationships between evidence and explanations.

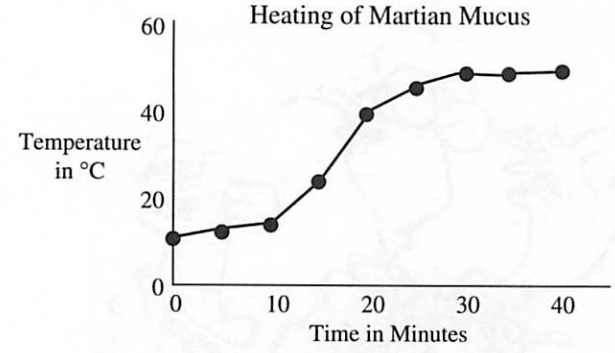
____ 6. Recognize and analyze alternative explanations and predictions.

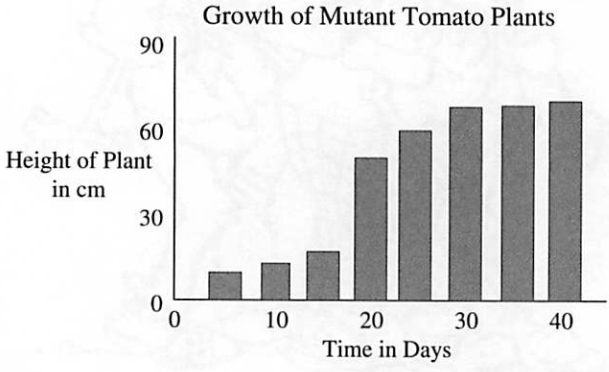
Types of Graphs

This section will give you some ideas on how you can use graphs to display the information you are going to collect as a graph. A graph is simply a picture of the data that you gathered portrayed in a manner that is quick and easy to reference. There are four kinds of graphs described on the next two pages. If you find you need a leg up in the graphing department, Loose in the Lab has a book about *Data Tables & Graphing*. It will guide you through the process.

Line and Bar Graphs

These are the most common kinds of graphs. The most consistent variable is plotted on the "x", or horizontal, axis and the more temperamental variable is plotted along the "y", or vertical, axis. Each data point on a line graph is recorded as a dot and then all of the dots are connected to form a picture of the data. A bar graph starts on the horizontal axis and moves up to the data line.

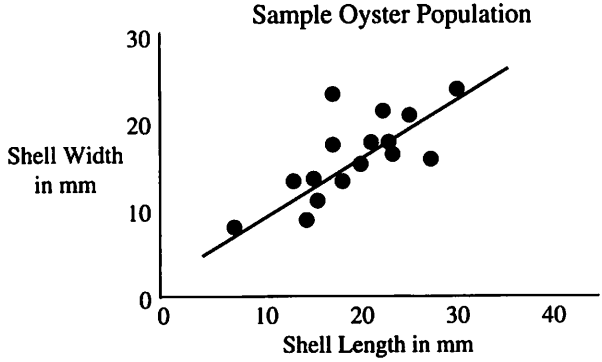




Types of Graphs

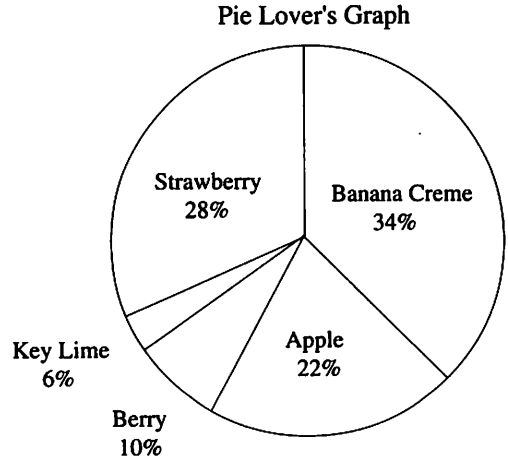
Best Fit Graphs

A best fit graph was created to show averages or trends rather than specific data points. The data that has been collected is plotted just as on a line graph, but instead of drawing a line from point to point to point, which sometimes is impossible anyway, you just free hand a line that hits "most of the data."



Pie Graphs

Pie graphs are used to show relationships between different groups. All of the data is totaled up and a percentage is determined for each group. The pie is then divided to show the relationship of one group to another.



Other Kinds of Data

1. Written Notes & Observations

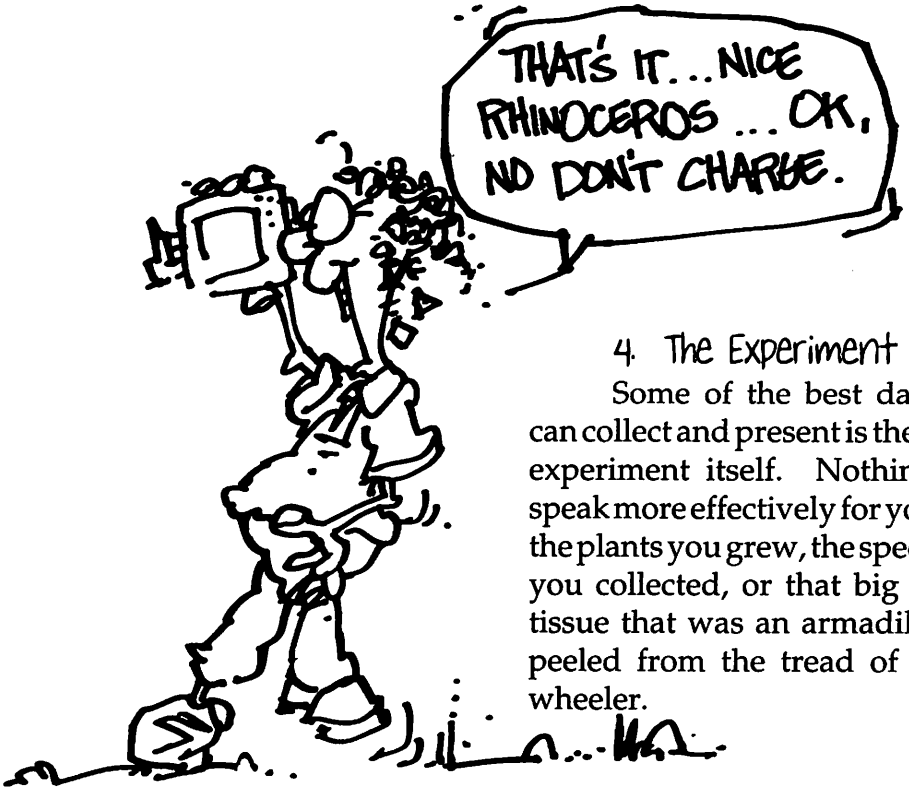
This is the age-old technique used by all scientists. Record your observations in a lab book. Written notes can be made quickly as the experiment is proceeding, and they can then be expounded upon later.

2. Drawings

Quick sketches as well as fully developed drawings can be used as a way to report data for a science experiment. Be sure to title each drawing and, if possible, label what it is that you are looking at.

3. Photographs, Videotapes, and Audiotapes

Usually better than drawings, quicker, and more accurate, but you do have the added expense and time of developing the film. However, they can often capture images and details that are not usually seen by the naked eye.



4. The Experiment Itself

Some of the best data you can collect and present is the actual experiment itself. Nothing will speak more effectively for you than the plants you grew, the specimens you collected, or that big pile of tissue that was an armadillo you peeled from the tread of an 18-wheeler.

Evaluating Your Data

Once your data is collected, it is time to sit down and let it tell a story. Let it describe the phenomena that you just witnessed. The following pages have some guide sheets that should help you evaluate your data and create interpretations from the numbers and squiggles that you collected.

The first sheet is going to ask you to describe, evaluate, predict, and create models from your data. We will state the question that will be posed and give you an example to help clarify the direction you should be going.

1. Descriptions

What does the data that you collected allow you to describe about your experiment?

This is almost a pure kind of observation. Think of yourself as a *reporter* in this instance. You are not trying to figure out why something happened or what it means in the context of world religion, you are just looking and reporting what you see. "Wow, that's big, it's very flat, smells like spinach souffle, and the sound is similar to the howling of a coyote." Stuff like that. Here are some more examples.

A. If you are looking at a graph of the temperature of a solution produced when two chemicals are mixed together, a description could be: "The heat released by the reaction of the two chemicals warmed the solution to 15 degrees Celsius in 5 minutes." Or . . .

B. If you are doing a chromatography experiment: "The colors produced by the super-fed marigold leaves were dark green, green, light green, dark yellow, and a thin band of orange."

C. And finally, from our new airplane-design competition: "The second wing provided additional lift that could be easily seen as the plane ascended toward the ceiling at twice the rate of any of the other previous plane designs."

Evaluating Data • Some Examples

2. Explanations

How does the data that you collected allow you to explain what you observed about your experiment?

You are now playing the thinking person's game. Think of yourself as an *analyst* in this instance. This requires that you evaluate the data and describe why it did what it did. An example:

A. "The plane rose toward the ceiling faster because the curve across the top of the airfoil had been increased by 7 degrees." You tell why it did what it did. Or. . .

B. "The super-fed marigolds had access to extra selenium in the soil that is believed to be a principal component in Chlorophyll C. Chlorophyll C produces a dark yellow band in chromatography experiments."

C. "The temperature of the water in the solution increases because the energy that the molecule was using to hold the atoms together was released as heat and that heat was absorbed by the water."

3. Predictions

What predictions, if any, are you able to make by using the data that you collected in your experiment?

Grab your crystal ball and make a prediction. Think of yourself as a *weatherman* in this instance. You are taking the existing data and using it to decide what might happen if . . .

A. "Given the heat of reaction in the original experiment it is entirely probable that doubling the amount of chemical could very easily double the temperature produced."

B. You haven't done the experiment, but based on what you have seen so far you are guessing or predicting what will happen next.

4. Models

Are there any models that you can create that would describe or explain the data and findings of your experiment?

A model can be a physical example, like a model of a molecule constructed from styrofoam balls and toothpicks or a set of data that represents a general trend like a model of a hurricane. It is not the exact hurricane but a representative model based on a lot of data. Some other examples:

A. "By taking chromatography samples from over 200 super-fed marigolds, we have developed a generalized model of what the color-band sequence would probably look like."

B. "Having measured the temperature increase of 1 liter of water, we have developed a mathematical model that allows us to predict the end temperature of the solution when any amount of chemical is mixed."

C. "Combining the two plane designs, we created a physical model that meets the rate-of-climb demands without stalling, that we were hoping to achieve."

Hopefully, that was more helpful than confusing. The work sheet we would like you to fill out is on the next page.

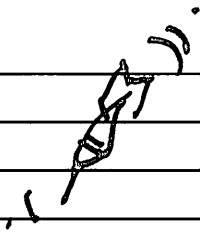
Evaluating Data Work Sheet

1. Descriptions

What does the data that you collected allow you to describe about your experiment?

2. Explanations

How does the data that you collected allow you to explain what you observed about your experiment?



3. Predictions

What predictions, if any, are you able to make by using the data that you collected in your experiment?

4. Models

Are there any models that you can create that would describe or explain the data and findings of your experiment?

Logically Connect Data with Explanations

Think critically and logically to make the relationships between evidence and explanations. One way to do this is to use the following sheet to help you sort out your thoughts.

1. Evidence

The evidence that I have supporting/refuting (choose one) my hypothesis is . . . _____

_____

_____

_____

2. Explanations

The reasons that this evidence supports/refutes (choose one) my hypothesis are:

A. _____

_____

_____

_____

B. _____

_____

_____

_____

C. _____

_____

_____

Explore Alternatives to Your Explanation

It is also very important for scientists to examine their work and be able to recognize and analyze alternative explanations and predictions that become evident from their research. This does not always happen but should be explored.

1. Evidence

The evidence that I have supporting/refuting (choose one) my hypothesis is...

_____

_____

_____

2. Alternative Explanations

In addition to the primary explanations I have given that this evidence supports/refutes (choose one) my hypothesis, there are other possible explanations that require more research and thought but may be just as viable.

A. _____

_____

_____

B. _____

_____

_____

C. _____

_____

_____

3. Modified Experiment

To examine this alternative explanation I would modify the original experiment by ...