Chapter 2

The Scientific Method

A science project is an investigation using the scientific method to discover the answer to a scientific problem. Before starting your project, you need to understand the scientific method. This chapter uses examples to illustrate and explain the basic steps of the scientific method. Chapters 3 through 5 give more details, and Chapter 6 uses the scientific method in a sample project. The **scientific method** is the "tool" that scientists use to find the answers to questions. It is the process of thinking through the possible solutions to a problem and testing each possibility for the best solution. The scientific method involves the following steps: doing research, identifying the problem, stating a hypothesis, conducting project experimentation, and reaching a conclusion.

RESEARCH

Research is the process of collecting information from your own experiences, knowledgeable sources, and data from exploratory experiments. Your first research is used to select a project topic. This is called topic research. For example, you observe different seeds in the kitchen and wonder if they will grow. Because of this experience, you decide to learn how seeds grow. Your topic will be about **germination.**

Once the topic is selected, you begin what is called project research. This is research to help you understand the topic, express a problem, propose a hypothesis, and design one or more project experiments—experiments designed to test the hypothesis. An example of project research would be planting pinto beans as an exploratory experiment. The result of this experiment and other research gives you the needed information for the next step—identifying the problem.

Do use many references from printed sources—books, journals, magazines, and newspapers—as well as electronic sources—computer software and on-line services.

Do gather information from professionals—instructors, librarians, and scientists, such as physicians and veterinarians.

Do perform other exploratory experiments such as those in the 50 science project ideas in Part II.

PROBLEM

The problem is the scientific question to be solved. It is best expressed as an "open-ended" question, which is a question that is answered with a statement, not just a yes or no. For example, "How does light affect the germination of bean seeds?"

Do limit your problem. Note that the previous question is about one period of seed development and one type of seed instead of all seeds. To find the answer to a question such as "How does light affect seeds?" would require that you test different periods of seed development and an extensive variety of seed types.

Do choose a problem that can be solved experimentally. For example, the question "What is a flashlight?" can be answered by finding the definition of the word *flashlight* in the dictionary. "What makes a flashlight bulb glow?" can be answered by experimentation.

HYPOTHESIS

A hypothesis is an idea about the solution to a problem, based on knowledge and research. While the hypothesis is a single statement, it is the key to a successful project. All of your project research is done with the goal of expressing a problem, proposing an answer to it—the hypothesis, and designing project experimentation. Then, all of your project experimenting will be performed to test the hypothesis. The hypothesis should make a claim about how two factors relate. For example, in the following sample hypothesis, the two relating factors are light and seed germination. One example of a hypothesis for the earlier problem question is:

"I believe that bean seeds do not need light during germination. I base my hypothesis on these facts:

- Seed packages instruct the user to plant seeds beneath the soil where it is dark.
- In my exploratory experiment, pinto beans germinated beneath the surface of soil in the absence of light."

Do state facts from past experiences or observations on which you based your hypothesis.

Do write down your hypothesis before beginning the project experimentation.

Don't change your hypothesis even if experimentation does not support it. If time permits, repeat or redesign the experiment.

PROJECT EXPERIMENTATION

Project experimentation is the process of testing a hypothesis. The things that have an effect on the experiment are called **variables**. There are three kinds of variables that you need to identify in your experiments: independent, dependent, and controlled. The **independent variable** is the variable you purposely manipulate (change). The **dependent variable** is the variable being observed that changes in response to the independent variable. The variables that are not changed are called **controlled variables.**

The problem in this chapter concerns the effect of light on seed germination. The independent variable for the experiment is light and the dependent variable is seed germination. Other factors could cause the dependent variable to change. To be sure that they don't affect the outcome, a **control** is set up. In a control, all variables are identical to the experimental setup—your original setup—except for the independent variable. Factors that are identical in both the experimental setup and the control setup are the controlled variables. For example, prepare the experiment by planting 3 or 4 different beans, one bean type per container. Place the containers in a dark closet so that they receive no light. If at the end of a set time period, the seeds grow, you might decide that no light was needed for germination. But, before making this decision, you must determine experimentally if the seeds would grow with light. Thus, a control group of plants must be set up so that the container receives light throughout the testing period. The other variables for the experimental and control setup, such as type of container, soil, amount of water, temperature, and type of seeds used must be kept the same. These are controlled variables.

Do have only one independent variable during an experiment.

Do repeat the experiment more than once to verify your results if time permits.

Do organize data. (See Chapter 6, "A Sample Project," for information on organizing data from experiments.)

Do have a control.

PROJECT CONCLUSION

The project conclusion is a summary of the results of the project experimentation and a statement of how the results relate to the hypothesis. Reasons for experimental results that are contrary to the hypothesis are included. If applicable, the conclusion can end by giving ideas for further testing.

If your results do not support your hypothesis:

Don't change your hypothesis.

Don't leave out experimental results that do not support your hypothesis.

Do give possible reasons for the difference between your hypothesis and the experimental results.

Do give ways that you can experiment further to find a solution.

If your results support your hypothesis:

For example, you might say, "As stated in my hypothesis, I believe that light is not necessary during the germination of bean seeds. My experimentation supports the idea that bean seeds will germinate without light. After 7 days, the seeds tested were seen growing in full light and no light. It is possible that some light reached the "no light" containers that were placed in a dark closet. If I were to improve on this experiment, I would place the "no light" containers in a light-proof box and/or wrap them in a light-proof material, such as aluminum foil."