**The Scientific Method**

**Experiments in Science**

A scientist once said that the greatest contribution ever given to science was the method of doing experiments. The experiment is one of the most important ways of obtaining scientific information.

An experiment allows a scientist to prove or disprove a hypothesis. If we were not able to experiment, we would have millions of hypotheses and no way to test them. This makes the experiment rather important in science.

An experiment has several parts: (1) The **Purpose**: Why the experiment is being done. It usually states the hypothesis that the scientist is trying to support or refute. (2) The **Apparatus**: The equipment that is used in an experiment. (3) The **Procedure**: the step-by-step instructions, which explain how the experiment is performed. (4) The **Results**: What happens as a result of the procedures done in the experiment. (5) The **Discussion**: An explanation and analysis of the results. (6) The **Conclusion**: A final statement that supports or refutes the original purpose of the experiment. All of these components are important to an experiment and are written up in a very special way for other scientists to review.

An experiment is something that can be repeated. Others can do the same experiment and find out if the results of the first experiment were true. This lets scientists check the knowledge that is produced by science. It is very important to have science experiments recorded clearly, so they can be of the greatest value to others.

A very important aspect of an experiment is called the control. A control makes sure that scientists are checking what they think they are checking. The control in an experiment is that part which contains all the components except the part being tested. An example can help explain this.

Jonas Salk developed the polio vaccine to combat the dreaded disease polio, which would cripple its victims. One of the final experiments involved thousands of school children. Half the children were given the vaccine and half were given a *fake* vaccine called a placebo. The placebo was the control. The placebo looked just like the vaccine and was given in exactly the same way. The control group was used as a comparison group. After a year, all the children were examined. No polio virus was found in the children receiving the real vaccine, while there were cases found with the children who received the placebo.

Without a control group in an experiment, Dr. Salk would not have known if the vaccine really worked even if no children contracted polio. All good experiments contain controls.

Scientists who do a great deal of experimenting are very skilled at thinking up ways to experiment. They become skilled in setting up controls. Sometimes scientists have to really stretch their imaginations to figure out experiments that will test what they want to test. This is part of their jobs and it can be very exciting.

**Problem Solving in Science**

How are problems solved in science? When scientists have a problem to solve, they follow the same steps that any good thinker uses. Let us take a problem see how scientists finally solved it.

In the early to mid-1800's, plantations in the Southern states used to raise cotton year after year in one field. They noticed the crops were getting worse each year and the soil harvest smaller. They planted the same kinds of seeds in the same way every year, yet the plants got smaller and there was less cotton to pick. When the plantation owners used land where no cotton had been raised before, the plants would grow very well for a while. Then after a few years the crops would again begin to fail. Everyone was puzzled.

Scientists and other specialists thought of all the things that might keep the plants from growing well. Poor crops might result from several years of bad weather. But the records showed that the weather had been fairly good during the past years, so the weather was probably not the cause of the poor crops.

Scientists knew growing plants take certain minerals from the soil. They learned this fact by finding out what materials plants are made of. The scientists thought that maybe the crops used up the minerals in the soil, and that is why the plants wouldn't grow well. This hypothesis needed to be tested.

Some experiments were conducted. First, the scientists decided to test the soil where the crops had been grown. If the crops took minerals from the soil, there would be a difference between the soil that had been used and the soil that had not been used to grow plants. The scientists took samples of both soils and tested each to find out what minerals were in it. They discovered that there was a difference between the two soils. The unused soil had more of the minerals that plants needed than the used soil had. They thought they were on the right track, but they still had not proved the lack of minerals in the soil was the cause of poor crops.

They had to do another experiment. Cotton should grow better if the minerals were put back into the soil. This was good thinking. They added the missing minerals to the soil, planted the seeds, and waited for the harvest. The result was just what they thought it would be. The plants grew well and produced a good crop for the first time in years.

But still they were not ready to say that the idea was answer. They repeated the experiments several times. Each time they got the same result. At last they were sure that they had found the real cause of poor crops. The crops had used up most of the minerals in the soil, and so the plants could no longer grow well. If the minerals were put back into the soil, the plants would grow better and produce good crops. We use this discovery whenever we put fertilizer on the soil to make it richer.

The way in which scientists think and work is called the scientific method. It is a very useful way to solve many different problems. Here are the steps that a scientist usually follows:

**Points to Ponder**

1.     Scientists focus on a problem they want to solve or a question they want to answer.

2.     They make many observations and think of as many ways as they can to solve the problem or to explain the facts that were found.

3.     They choose a solution or explanation that seems to be correct and form a hypothesis.

4.     They plan and do an experiment to test whether the solution or explanation is correct.

5.     If the experiment seems to show that the solution or explanation is correct, they make sure that it is correct by doing other experiments to test it.

The fifth and last step in the scientific method is very important. Careful scientists always verify discoveries. In other words, scientists prove discoveries to be true by testing them in many different ways. When scientists announce a discovery, they usually tell how they did the experiments and how they verified the results. Other scientists repeat these experiments and also try new ones to test the original results. They want to make sure that the discovery is true before they believe it. A good scientist does not accept a new discovery until it has been carefully verified.

**The Scientific Method**

You can often read about men and women of science making discoveries. In many of these situations, you will find that the scientific method was used.

These are 5 steps to the scientific method:

 **1. Asking a question or seeing a problem to be solved**

 **2. Making observations and thinking of possible solutions**

 **3. Choosing the best solution and forming a hypothesis**

 **4. Performing tests or experiments**

 **5. Re-testing and drawing conclusions**

The paragraph below describes how the polio vaccine was developed and tested by Dr. Jonas Salk. Read the paragraph carefully. Look at the listing below it to see how the steps of the scientific method were followed.

In the early 1950's, nearly 50,000 people were stricken with polio. Hundreds of medical researchers were trying to find an effective way to prevent this dreaded disease. Among them was Dr. Jonas Salk. Salk investigated various methods and decided to produce a possible vaccine. He tried several types in experiments with monkeys and, as a result, developed a vaccine that contained "inactive" polio virus. After perfecting this vaccine in the laboratory, Salk tested it with several hundred people and found it to be safe. Then it had to be tested on a large scale. In nationwide field tests in 1954, over 440,000 children were vaccinated with Salk's vaccine. The tests compared the real vaccine to a "fake" vaccine called a placebo. A placebo acts like a control in an experiment. These tests, and additional tests in Canada and Denmark, showed the vaccine to be nearly 100% effective.

**Review Questions**

Complete the following:

 1. What was the problem?

 2. What were some possible solutions?

 3. What was the "best solution" Salk chose to try?

 4. How did he experiment?

 5. How did he verify the results?

 6. Why was a control used in the experiment?

**PRACTICE WITH THE SCIENTIFIC METHOD**

Baking Pies

*Directions*: Read the following paragraph carefully. Then show how the scientific method was used by filling in the correct information opposite the five steps listed below.

Mr. Jones had a reputation for making excellent pies. One day he baked a pie using a new recipe. The pie was a complete failure. What could have happened? Mr. Jones was anxious to keep his fine reputation so he decided to investigate. He carefully checked his stove, the ingredients he had used, and the recipe. As he reread the recipe he noticed that it had been developed by a company located in Denver, Colorado. Mr. Jones did some research and found that the amounts of certain ingredients had to be changed at different heights above sea level if the same pie recipe was to be used successfully. First he determined the changes needed. Then he made the pie many times. At last, he had what seemed to be perfect proportions of ingredients for the area in which he lived. After that, he made many delicious pies using the recipe, which had almost ruined his pie-baking reputation.

 1. PROBLEM:

 2. POSSIBLE SOLUTIONS:

 3. CHOICE OF SOLUTIONS:

 4. EXPERIMENT:

 5. VERIFYING THE RESULTS:

**MORE PRACTICE WITH THE SCIENTIFIC METHOD**

Pasteur

*Directions*: Read the following paragraph carefully. Then show how the scientific method was used by filling in the correct information opposite the five steps listed below.

Louis Pasteur was a famous scientist. He often wondered why milk spoiled so quickly. He thought it might be the breed of cow that caused the problem. He also thought it might be microscopic bacteria or germs that were causing the premature spoiling of the milk. He tested the second idea by boiling milk to kill the germs. He compared it to an identical sample that was not boiled. He repeated the experiment several times, and had other scientists do the same. The results were all the same: the boiled milk spoiled at a much slower rate than the other milk. This process carries his name, "pasteurization".

1. What was the problem for Pasteur?
2. What were his possible solutions?
3. What was his choice for a solution
4. How did he test his choice?
5. How did he verify his facts?
6. What was the "control" group in his experiment?

**Do an Experiment Using the Scientific Method**

**Scientific Method Study Guide**

**Part I.** *Directions*: For each of the following definitions, give the word it defines.

 1. a procedure designed to test a hypothesis

2. a theory that has withstood the test of time

3. information collected as observations and measurements

4. any information that comes through our senses

5. What I want to know and/or find out? - Always a question.

6. a possible answer based on observations

7. a logical step-by-step method for "doing science"

8. a hypothesis that has withstood repeated testing

9. the part of the experiment which there is no changes, it is used for comparison

10. a variable that may affect the results of an experiment

**Part II.** *Directions*: For each of the following, complete the statement or answer the question.

1. When testing a hypothesis it is good idea to use a control because
2. In order to prove a hypothesis you must
3. Which of the following will never change?

a. Variable

b. Scientific law

c. Hypothesis

d. Theory

1. A concept that was recently formed from an educated guess but not proven over time is
2. The Wright brothers designed and built a plane named or commonly referred to as
3. Why is it important to record all of the units when recording data?
4. If a hypothesis is not supported by the results of an experiment, it must be
5. Which of the following is not a scientific observation of an object?

a. it is 3.4 cm long

b. it is red

c. it is pretty

d. it has a mass of 3 g

1. In a controlled experiment to test the effects of the shape of a paper plane on how well it will fly, which of the following variables should be the same in each test?

a. type of paper

b. wing width

d. wing tears or flaps

**Part III.**    *Directions*: give brief but complete answers to the following questions.

1. All of the goldfish in an aquarium are found dead one morning. Briefly explain how you might proceed scientifically to find out why this happened.
2. List what changes you made to your planes and how each change affected their flight.
3. Why is it that the instructions in the Scientific Method Lab said to change only one aspect of your plane each time?
4. What relationship did the size of your plane's wings have on the distance it flew?