

# Keys to a Successful Project

## 1. Your Question - The essential starting point for your project.

Science is asking a question of nature and making sense out of the answer. Engineering is figuring out how to solve some problem by designing a new way to make or do something and showing that it works.

**A science or engineering research project is ONLY as good as the question on which it is based.**

You will want to choose a question that can be answered by some experiments that YOU can do by yourself, with only a little help from others.

If your question is "How do volcanoes work?" you will probably not do very well. That question is just too complex and needs much harder experiments than you are likely to have time, equipment or skills to handle.

If your question is "Do rats jump if you step on their tails?" you also will not do well. That question is too simple, not to mention that to do the experiment would be rather cruel. We do not allow any experiments on vertebrate animals that might harm them.

A good question is clear and direct and helps you see what experiment to do to answer it. The best questions will also lead naturally into other questions by which you can extend what you are able to learn by some related experiments.

Now, let's look at a concrete example of how you might go about developing your question. For example, you might decide that you would like to know something about why cockroaches go to certain places in a house more than others. That is a general statement of what you are interested in learning. Your specific question (which suggests a particular experiment that could be the center of your research project) might be:



*"What colors of floor material do cockroaches (Blattidae) prefer?"*

## **2. Gathering Data or Recording nature's answers to your question.**

Having a question and thinking of some experiment that could give you an answer to that question is only the beginning. Now you have to do the experiment and write down what happens. Data are the numbers, observations, and other things you can write down to say what happened when you did your experiment. Some data you get by counting, some by measuring with an instrument (like a thermometer or a voltmeter, etc.) and some is simply your written description of what you saw.

In the cockroach experiment you might DESCRIBE the various floor colors you tried and also COUNT the number of cockroaches that you found on each color. You might also MEASURE the brightness of the light (with a photographic exposure meter, for example) and maybe MEASURE the temperature of the different colored floors (with a thermometer or thermocouple).

You will need to have a "logbook." This is a research notebook in which you write your data, and it is also a place to record what you did to produce those data.

You need to bring your research notebook to the Fair as a part of your exhibit. The judges will be looking for your observations and data, so be sure you write down each day as you do the experiments, not later on after all the experiments are done.

## **3. Precision also known as "How well did you measure it?"**

Data are only useful if you can believe them. One important test of your data is: *Do you get the same results when you repeat the experiment a second (or third, or tenth) time?*

Try it and see. Notice how much the answers you get change from the first time you do the experiment to the next time. None of the answers you get is more correct than any other, so each answer is uncertain by about as much as any one answer differs from another.

This is called the "Precision" or "Repeatability" of your data. If you are doing a physics experiment, you probably can just measure the same thing several times with the same apparatus. If you are doing a biology or psychology experiment, you may need to repeat your experiment several times using many different subjects (different plants or different people) each time.

In the cockroach experiment, you could repeat the experiment several times with a new handful of roaches for each pair of floor materials you are testing.

Suppose when you do your experiment five times, the numbers you get (for example, the number of roaches on one particular color of floor) are 76, 79, 72, 81, and 74. The average of these numbers is 76.4. But you should not conclude that the "correct" value is 76.4: that would be claiming more than you really know. Instead, you could say "after five measurements the answers ranged from 72 to 81 with an average of 76." That tells both what the average value was and something about how much the different values you recorded varied from one another. Another, more technically complete, method of giving this information would be to say, "In five measurements, the average value was 76.4 with a standard deviation of the mean of 1.6." If you wish to learn how to do this more mathematical kind of data analysis, consult any standard book on experimental statistics. We especially encourage high school students to use this approach.

Record your data in a table or chart and then plot them. This will help you (and the judges) "see" what is going on.

#### **4. Controls, also known as "How do you know that what happened was because of what you did?"**

Your experiment will very likely attempt to answer some sort of "What if..." question. You are trying to find out what happens when you change something about the situation.

In the cockroach experiment you will be looking for changes in the number of roaches that choose either of the two floor colors in the box when you change their choice of colors.

It is important to be sure that the differences you see are, in fact, caused by the changes you meant to make, and not by something else you just didn't notice.

If you had two regions of colored floor, one black and one white, and they were both under a strong light, the black floor would get hotter. If the cockroaches preferred the black floor, you might actually be observing their preference for a warmer area and not really a preference for a darker color.

Repeating your experiment is one way to check on this. If you don't get the same result when you repeat the experiment, clearly you are not measuring what you thought you were (or, something else is also happening). Another way to check on your results is to use a CONTROL situation.

A related question is how accurate your measuring instruments are. You may be able to read the temperature indicated on your thermometer to within one-tenth of a degree, but what if the thermometer is not measuring the actual temperature of the floor or whatever you wanted to measure? Or what if it is not calibrated correctly - it might be wrong by five degrees?! (You could, perhaps, check that by using a second thermometer.)

#### **5. Analysis or Making sense of what you have done.**

Most likely, no experiment will actually answer your question for you. You have to look at the data and then do some organized

thinking about these data to arrive at an answer to your question.

Sometimes you will have to make a graph of your data, or compute some averages, or compare what you measure to what someone else has measured in a different situation.

Your work is still not done. Doing an experiment and taking some data is not all there is to science. You must figure out what it all means. And then you can tell others (including the judges) what you figured out.

After you have presented all the data you took in a way that lets you see some patterns you should write down what you think it all means. State your conclusion and your reasons for them.

Your logbook is a very good place to put all these graphs, computations, etc. That way all your work is shown in one place. Later on, when you prepare your display, you may copy just those graphs that best show your results.

## **6. The Research Report or Tell us all about it.**

The logbook, if you use it correctly, will have all the details of what you did and what you saw and what you calculated and what that all means to you. But it will, very likely, not be easy to read and understand.

A complete science research project will include preparing a research report. This is an organized representation of the information in the logbook (or at least the most essential parts of that information). The reason for representing it is to put it together in a way that makes it easier to read and understand. An excellent science fair display will have the research report and the logbook attached to the display panels.



## Additional Tips For a Good Project

The Scientific Method is a logical process to arrive at the best answers to questions based on observable facts. The method provides good answers when using the following:

### **STATEMENT OF THE PROBLEM OR QUESTION:**

A clear, short statement of the investigation problem or question must be worked out so that any observer can understand what you are doing.

*Example: Can houseflies distinguish between artificial sweetener and sugar?*

### **HYPOTHESIS:**

A hypothesis is a statement that serves as a possible explanation or answer to a problem or question. It can also serve to give direction to your investigation or experiments. Your hypothesis is to test, not to prove.

*Example: If houseflies can distinguish artificial sweeteners from sugar, they will respond or behave in a different manner when fed the two substances.*

### **RESEARCH:**

Search the literature (books, magazines, journals) and take notes on what others have learned about your topic. Often personal interviews with experts on your subject will be of great value. You need to know a lot about your topic before you can design and carry out good investigations and experiments. WARNING: The internet is a great resource for information, but do not rely on it solely. Much of the information obtained online is misleading and of little value.

*Example: Look up and take notes on houseflies and their behavior, the feeding mechanism of insects; learn about sugar and artificial sweeteners.*

## **EXPERIMENTATION:**

A good experimental design will allow you to gather factual information on your problem and test your hypothesis. Accuracy in measurement is vital when recording your data. Remember, **your hypothesis is to test, not to prove.**

*Example: Fifty houseflies were selected to be tested for 10 trials in sugar solution (10%) and artificial sweetener (10%). Each fly was glued to a small stick by the wings and during the trial the flies' feet were immersed in the solutions. The observation recorded was the extension of the flies' proboscises into the solutions.*

When setting up your experimental design, use the following guidelines:

**Control the Variables.** You must eliminate other factors that could alter or influence your results. (Nothing should vary in the fly problem but the sugar and the artificial sweetener. Everything else must be the same: temperature, light, time of day, condition of the flies, etc.)

**Collect DATA.** During your experiment you must indicate in detail what you did and how you did it, and all of your observations. The data should be quantitative where possible (how much, how high, how hot.)

*Example: 47 out of 50 flies lowered their feeding proboscises when placed on sugar water; whereas 3 out of 50 flies lowered their feeding proboscises when placed on artificial sweetener "A."*

**Sample Properly:** Use as many trials or subjects as practical to eliminate any individual differences.

**Ensure Reproducibility:** Your experiment must be designed and described so that others following your procedure would get the same results.

**Analyze and Display Data:** After collecting your data, it must be organized, analyzed and displayed in tables or graphs.

*Example: The results of the 10 trials in sugar and 10 trials in sweetener “A” should be listed on a table and the average ( $\bar{x}$ ), standard deviation ( $s$ ), and probability ( $p$ ) should be calculated. (You may need help to learn to do the calculations.)*

## **CONCLUSION:**

Discuss how the data (your results) compare with your hypothesis. Was your hypothesis correct? You cannot change the data, but you could alter or modify your hypothesis and perhaps design and run a new set of experiments.

*Example: The fly experiment data supports the hypothesis that house flies can distinguish between the two substances. They appear ready to feed on the sugar, but not on the artificial sweetener “A.”*