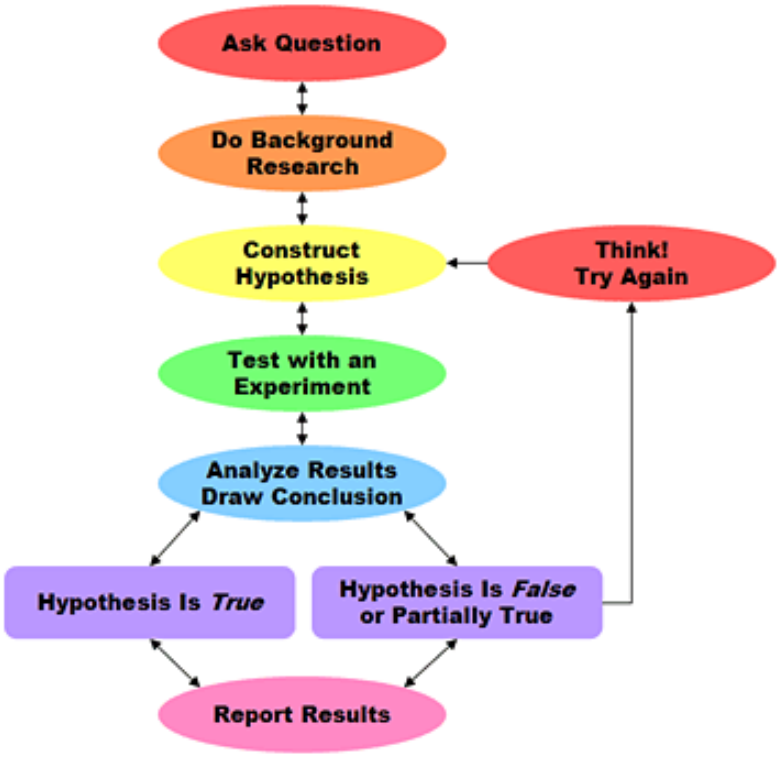
Overview of the Scientific Method

The scientific method answers questions. We design an experiment to help us answer those questions. It helps you to focus your science fair project question, construct a hypothesis, design, execute, and evaluate your experiment.



Steps of the Scientific Method

Ask a Question

The scientific method starts when you ask a question - How, What, When, Who, Which, Why, or Where? In order for the scientific method to answer the question, it must be about something that you can measure, preferably with a number.

Do Background Research

Rather than starting from scratch, be a savvy scientist and use the library and Internet to help you find the best way to do things and don't repeat mistakes from the past.

Hypothesis

A hypothesis is your best answer to the question,

"If _____ *[I do this]*_____, then _____ *[this]*_____ will happen."

You must state your hypothesis in a way that you can easily measure. Construct it in a way to help you answer your original question.

Test Your Hypothesis by Doing an Experiment

Your experiment tests whether your hypothesis is true or false. Your experiment must be a fair test. You conduct a fair test by making sure that you change only one variable.

You should also repeat your experiments several times to make sure that the first results weren't just an accident.

Analyze Your Data and Draw a Conclusion

Once your experiment is complete, collect your data. You then analyze your data to see what it means.

If your data shows your hypothesis was false, that's okay! You can develop a new hypothesis; you can modify your experiment; or, after repeating your experiment several times, you can accept your data.

Communicate Your Results

You will communicate your results to others in a final report and a display board. Scientists call this "publishing your results."

Science Journal

As you do your project, you must keep a science journal. This will contain your ideas, research information, data, analysis, and conclusions.

What Makes A Great Science Journal?

(modified from a paper by Joanne Rebbeck, PhD, found at http://www.sciencebuddies.com)

Scientists keep records as they do their work. This is a science journal. Your science journal will be one of your most important tools as you do your science fair project.

1. Use a hardbound book. A journal is a good choice. This way, you will have everything you need in one place.

2. Use a pen to make your entries.

3. Always write the date of your entry. How you write your entries is not important. It doesn't even have to be neat! Just make sure you will be able to read it when you go back and review what you have done.

4. Whenever you do something for your science fair project, record what you do in your journal. It doesn't matter if it's important or not. This is a complete record of what you do. You can also draw pictures, make tables, etc. Remember, this is your record. Make it work for you!

5. If you want to put loose items in your journal (for example, pictures), make sure you glue them into your book.

6. Record everything that happens. It doesn't matter if it's a failure, mistake, etc. Once again, you want a complete record.

7. Record your thoughts as you do your project. What is working; what isn't working; what are you learning; anything that will help you learn from your project.

8. Make sure there's some order to your journal. You do forget things. Your journal will be your other "memory."

Asking a Question

This is your science fair project. Your question guides what you do. Select a question about a topic that interests you!

A scientific question usually starts with: How, What, When, Who, Which, Why, or Where.

Some things you should consider as you come up with your question include:

- Will your experiment be able to actually measure changes?
- Is your experiment safe to perform?
- Do you have all the materials and equipment you need for your science fair project, or will you be able to obtain them quickly and at a very low cost?
- Do you have enough time to do your experiment before the science fair? For example, most plants take weeks to grow. If you want to do a project on plants, you need to start very early! For most experiments, you will want to allow enough time to do a practice run in order to work out any problems in your procedures.
- Does your science fair project meet all the requirements for your science fair?

Here are examples of good questions.

- How does water purity affect surface tension?
- When is the best time to plant soybeans?
- Which material is the best insulator?
- How does arch curvature affect load-carrying strength?
- How do different foundations stand up to earthquakes?
- What sugars do yeast use

These are examples of unacceptable science fair project topics.

Topic	Why
Anything that is a simple preference or taste comparison. For example, "Which tastes better: Coke or Pepsi?"	These are surveys and not experiments.
Most consumer product testing of the "Which is best?" type. This includes comparisons of popcorn, bubblegum, make-up, detergents, cleaning products, and paper towels.	These projects only have scientific validity if the Investigator fully understands the science behind why the product works and applies that understanding to the experiment. While many consumer products are easy to use, the science behind them is often at the level of a graduate student in college.

Topic	Why
Any topic that requires people to recall things they did in the past.	The data tends to be unreliable.
Effect of music or talking on plants	Difficult to measure.
Effect of running, music, video games, or almost anything on blood pressure	The result is either obvious (the heart beats faster when you run) or difficult to measure with proper controls (the effect of music).
Effect of color on memory, emotion, mood, taste, strength, etc.	Highly subjective and difficult to measure.
Any topic that requires measurements that will be extremely difficult to make or repeat, given your equipment.	Without measurement, you can't do science.
Any topic that requires dangerous, hard to find, expensive, or illegal materials.	Violates the rules of virtually any science fair.

Developing a Hypothesis

Write your hypothesis so you experiment will test your hypothesis. A way you can state your hypothesis is: "If a particular independent[1] variable is changed, then there is also a change in a certain dependent variable[2]."

Example Hypotheses

- "If I open the faucet [faucet opening size is the independent variable], then it will increase the flow of water [flow of water is the dependent variable].
- "If a plant receives fertilizer [having fertilizer is the independent variable], then it will grow to be bigger than a plant that does not receive fertilizer [plant size is the dependent variable]."

---

[1] ***Independent Variable*** **-** the variable you change during your experiment.

[2] ***Dependent Variable*** **-** the variable you observe-changes in the dependent variable depend on changes in the independent variable.

- "If I put fenders on a bicycle [having fenders is the independent variable], then they will keep the rider dry when riding through puddles [the dependent variable is how much water splashes on the rider]."

Note: when you write your own hypothesis, you can leave out the part in the above examples that is in brackets [ ].

In each of the examples, it will be easy to measure the independent variables. This is another important characteristic of a good hypothesis. If we can readily measure the variables in the hypothesis, then we say that the hypothesis is **testable**.

Not every question can be answered by the scientific method. The hypothesis is the key. If you can state your question as a testable hypothesis, then you can use the scientific method to obtain an answer.

Materials List

What type of supplies and equipment will you need to complete your science fair project? By making a complete list ahead of time, you can make sure that you have everything on hand when you need it. Some items may take time to obtain, so making a materials list in advance represents good planning!

Make the materials list as specific as possible, and be sure you can get everything you need before you start your science fair project.

A Good Materials List Is Very Specific	A Bad Materials List
500 ml of de-ionized water	Water
Stopwatch with 0.1 sec accuracy	Clock
AA alkaline battery	Battery

What Makes a Good Materials List?	For a Good Materials List, You Should Answer "Yes" to Every Question
Have you listed all necessary materials?	Yes / No
Have you described the materials in sufficient detail?	Yes / No

Developing an Experiment

Key Elements of the Experimental Procedure

- Description and size of all experimental and control groups, as applicable
- A step-by-step list of everything you must do to perform your experiment. Think about all the steps that you will need to go through to complete your experiment, and record exactly what will need to be done in each step.
- The experimental procedure must tell how you will change your one and only independent variable and how you will measure that change
- The experimental procedure must explain how you will measure the resulting change in the dependent variable or variables
- If applicable, the experimental procedure should explain how the controlled variables will be maintained at a constant value
- The experimental procedure should specify how many times you intend to repeat your experiment, so that you can verify that your results are reproducible.
- A good experimental procedure enables someone else to duplicate your experiment exactly!

What Makes a Good Experimental Procedure?	For a Good Experimental Procedure, You Should Answer "Yes" to Every Question
Have you included a description and size for all experimental and control groups?	Yes / No
Have you included a step-by-step list of all procedures?	Yes / No
Have you described how to the change independent variable and how to measure that change?	Yes / No
Have you explained how to measure the resulting change in the dependent variable or variables?	Yes / No
Have you explained how the controlled variables will be maintained at a constant value?	Yes / No
Have you specified how many times you intend to repeat the experiment (should be at least three times), and is that number of repetitions sufficient to give you reliable data?	Yes / No
The ultimate test: Can another individual duplicate the experiment based on the experimental procedure you have written?	Yes / No
If you are doing an engineering or programming project, have you completed several preliminary designs?	Yes / No

Sample Materials List & Experimental Procedure

Materials List

- CD player & a CD (low drain device)
- Three identical flashlights (medium drain device)
- Camera flash (high drain device)
- AA size Duracell and Energizer batteries
- AA size of a "heavy-duty" (non-alkaline) battery (I used Panasonic)
- Voltmeter & a AA battery holder
- Kitchen timer

Experimental Procedure

1. Number each battery so you can tell them apart.
2. Measure each battery's voltage by using the voltmeter.
3. Put the same battery into one of the devices and turn it on.
4. Let the device run for thirty minutes before measuring its voltage again. (Record the voltage in a table every time it is measured.)
5. Repeat #4 until the battery is at 0.9 volts or until the device stops.
6. Do steps 1–5 again, three trials for each brand of battery in each experimental group.
7. For the camera flash push the flash button every 30 seconds and measure the voltage every 5 minutes.
8. For the flashlights rotate each battery brand so each one has a turn in each flashlight.
9. For the CD player repeat the same song at the same volume throughout the tests.

Conducting the Experiment

Preparations

You are almost ready to start your science experiment. Before you begin, there are still a few more things to do:

- **Know what to do.** Read and understand your experimental procedure. Have you written down all necessary steps? Do you have any questions about how to do any of the steps?
- **Get your science journal**.

- **Be prepared**. Collect and organize all materials, supplies, and equipment you will need to do the experiment. Do you have all of the materials you need? Are they handy and within reach of your workspace?
- **Think ahead about safety!** Are there any safety precautions you should take? Will you need adult supervision? Will you need to wear gloves or protective eye gear? Do you have to pull long hair back out of your face? Will you need to be near a fire extinguisher?

Data Table

Prepare a **data table** in your science journal to help you collect your data.

Sample Data Table

Trial	Faucet Opening (the Independent Variable)	Water Flow (the Dependent Variable)
#1	1/4 open	[Write your data in this column as you make measurements during your experiment.]
#2	1/4 open	
#3	1/4 open	
#4	1/2 open	
#5	1/2 open	
#6	1/2 open	
#7	3/4 open	
#8	3/4 open	
#9	3/4 open	
#10	Fully open	
#11	Fully open	
#12	Fully open	

Note: Some experiments will require additional columns for two or more dependent variables.

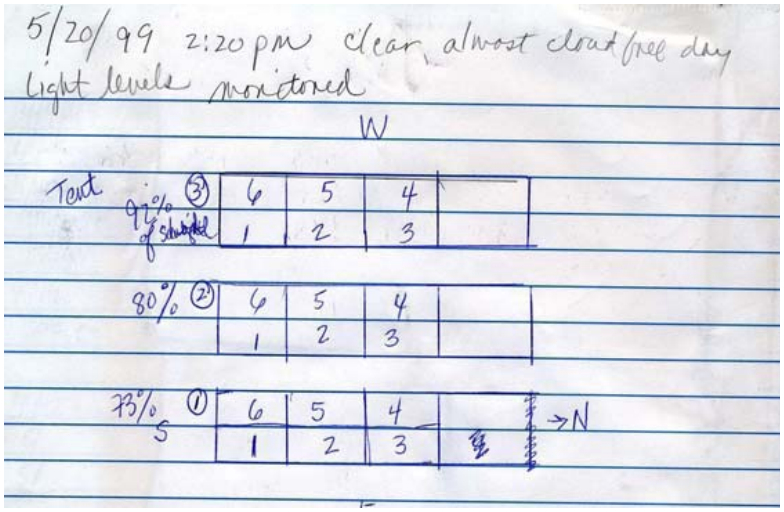
During the Experiment

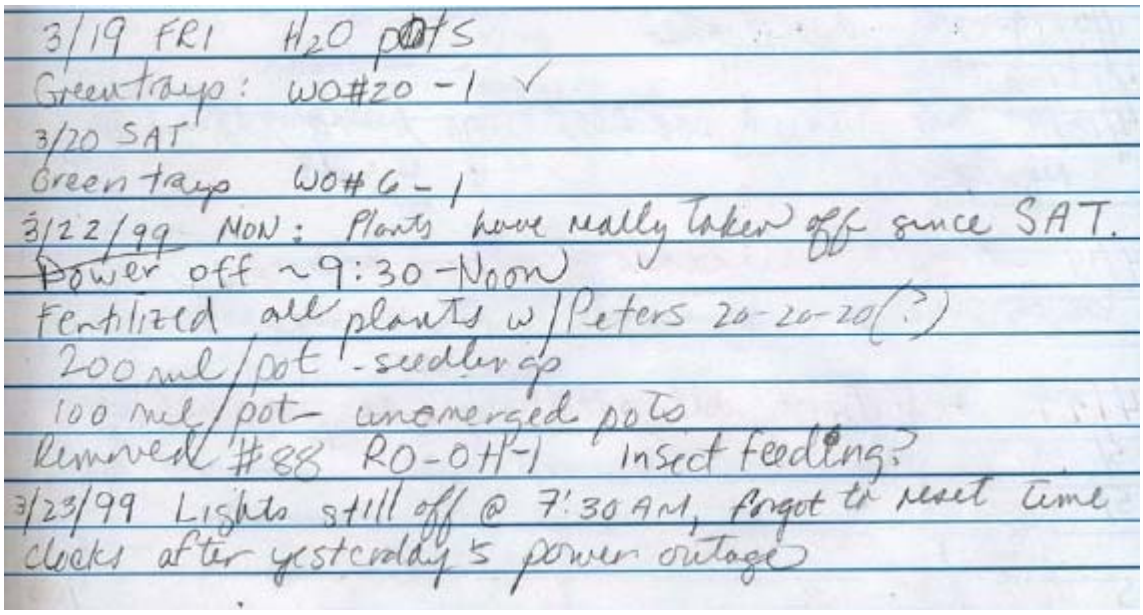
Take detailed notes as you conduct your experiments. Record your **observations** as you perform the experiment. Write down any problems that occur, anything you do that is different from planned, ideas that come to mind, or interesting occurrences. Be on the lookout for the unexpected. Your observations will be useful when you analyze your data and draw conclusions.

If possible, take **pictures** of your experiment along the way, these will later help you explain what you did and enhance your display for the science fair.

Remember to use numerical measurements as much as possible. If your experiment also has qualitative data (not numerical), then take a photo or draw a picture of what happens.

Examples from Journals





Be as exact as possible about the way you conduct your experiment, taking your measurements, and note taking. Failures and mistakes are part of the learning process, so don't get discouraged if things do not go as planned the first time. You should have built enough time in your schedule to allow you to repeat your test a couple of times.

1/4/05 my cat, Sheba scratched the pots of soil, and ate 4 of my 12 plants. I will have to replant everything! I need to protect plants from the silly cat. Maybe i should try putting a screen around the pots or keep cat outside!	2/5/05 Disaster in the lab this morning. Setup manure digoestors last night in incubators, temperature was set at 25 °C but came into a real mess, samples heated up too much and caps blew off. I will need to try a lower temperature to avoid this accident from happening again!!!! HUGE MESS TO CLEAN UP.....

It's a good idea to do a quick **preliminary run** of your experiment. Show your preliminary data to your teacher, and revise your experimental procedure if necessary. Often there are glitches in the procedure that are not obvious until you actually perform your experiment--this is normal. If you need to make changes in the procedure (which often happens), write down exactly the changes you made.

Stay organized and be safe! Keep your workspace clean and organized as you conduct your experiment. Keep your supplies within reach. Use protective gear and adult supervision as needed. Keep any chemicals away from pets and younger brothers or sisters.

What Makes a Good Science Experiment?	For a Good Science Experiment, You Should Answer "Yes" to Every Question
Did you take detailed notes about your observations and record them in your laboratory notebook?	Yes / No
Did you collect your data using a data table?	Yes / No
Were you consistent, careful, and accurate when you made your measurements?	Yes / No
Were you careful to insure that your controlled variables remained constant so as not to affect your results?	Yes / No
If you ran into any unexpected problems, did you adjust your experimental procedure accordingly?	Yes / No
If you are doing an engineering or programming project, have you involved some of your targeted users in the testing of your prototype?	Yes / No

Data Analysis

Take some time to review all of the data you have collected from your experiment. Use charts and graphs to help you analyze the data and patterns. Did you get the results you had expected? What did you find out from your experiment?

Think about what you have discovered and use your data to help you explain why you think certain things happened.

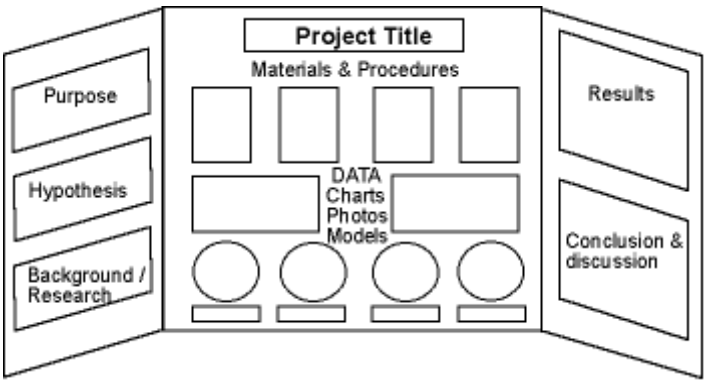
Often, you will need to perform calculations on your raw data in order to get the results from which you will generate a conclusion. A spreadsheet program such as Microsoft Excel may be a good way to perform such calculations, and then later the spreadsheet can be used to display the results. Be sure to label the rows and columns--don't forget to include the units of measurement (grams, centimeters, liters, etc.).

You should have performed multiple trials of your experiment. Think about the best way to summarize your data. Do you want to calculate the average for each group of trials, or summarize the results in some other way? Is it better to display your data as individual data points?

What Makes for a Good Data Analysis Chart?	For a Good Chart, You Should Answer "Yes" to Every Question
Is there sufficient data to know whether your hypothesis is correct?	Yes / No
Is your data accurate?	Yes / No
Have you summarized your data with an average, if appropriate?	Yes / No
Does your chart specify units of measurement for all data?	Yes / No
Have you verified that all calculations (if any) are correct?	Yes / No

What Makes for a Good Graph?	For a Good Graph, You Should Answer "Yes" to Every Question
Have you selected the appropriate graph type for the data you are displaying?	Yes / No
Does your graph have a title?	Yes / No
Have you placed the independent variable on the x-axis and the dependent variable on the y-axis?	Yes / No
Have you labeled the axes correctly and specified the units of measurement?	Yes / No
Does your graph have the proper scale (the appropriate high and low values on the axes)?	Yes / No
Is your data plotted correctly and clearly?	Yes / No

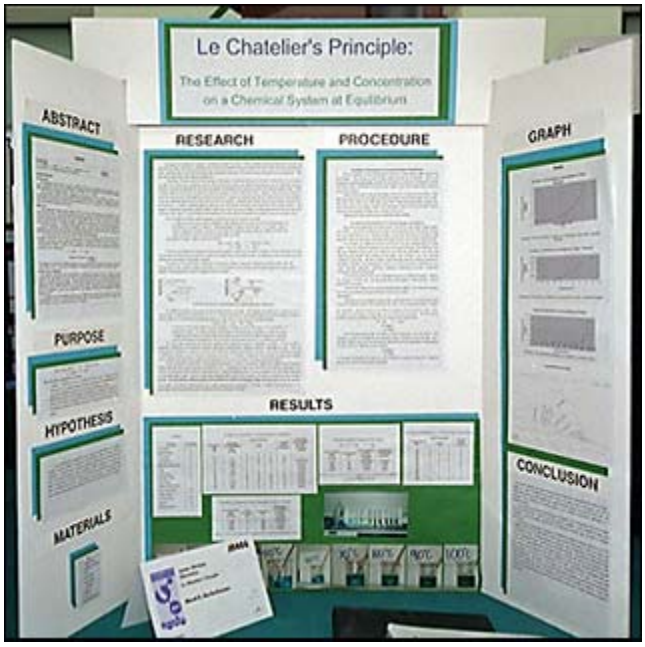
Display Board



You must have a display board for your project. You are required to purchase this display board.

Print out or write your information on white paper that you will attach to your display board. Be sure to proofread each sheet before you attach it.

This sample shows how difficult it can be to read text when you print it on top of an image. Don't do it!



Glue sticks (use plenty) work well for attaching sheets of paper to your display board. Use double-sided tape for items like photographs that may not stick to glue. Tip: Instead of regular paper, use cover stock (67#) or card stock (110#). These heavier papers will wrinkle less when you attach it to your display board, especially if you use a glue stick. Matte paper is preferable to glossy because it won't show as much glare— glare makes your display board difficult to read.

Use color construction paper to add accents to your display board. You can put sheets of construction paper behind the white paper containing your text.

What Makes for a Good Science Fair Project Display Board?	For a Good Science Fair Project Display Board, You Should Answer "Yes" to Every Question
Does your display board include: • Title • Abstract • Question • Variables and hypothesis • Background research • Materials list • Experimental procedure • Data analysis and discussion including data chart(s) & graph(s) • Conclusions (including ideas for future research) • Acknowledgements • Bibliography	Yes / No
Are the sections on your display board organized like a newspaper so that they are easy to follow?	Yes / No
Is the text font large enough to be read easily (at least 16 points)?	Yes / No
Does the title catch people's attention, and is the title font large enough to be read from across the room?	Yes / No
Did you use pictures and diagrams to effectively convey information about your science fair project?	Yes / No
Have you constructed your display board as neatly as possible?	Yes / No
Did you proofread your display board?	Yes / No
Did you follow all of the rules pertaining to display boards for your particular science fair?	Yes / No