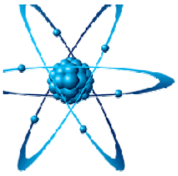


Variables in Your Science Fair Project

Scientists use an experiment to search for **cause and effect** relationships in nature. In other words, they design an experiment so that changes to one item cause something else to vary in a predictable way.

These changing quantities are called **variables**. A variable is any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and controlled.

The **independent variable** is the one that is changed by the scientist. To insure a fair test, a good experiment has only one independent variable. As the scientist changes the independent variable, he or she **observes** what happens.

The scientist focuses his or her observations on the **dependent variable** to see how it responds to the change made to the independent variable. The new value of the dependent variable is caused by and depends on the value of the independent variable.

For example, if you open a faucet (the independent variable), the quantity of water flowing (dependent variable) changes in response--you observe that the water flow increases. The number of dependent variables in an experiment varies, but there is often more than one.

Experiments also have **controlled variables**. Controlled variables are quantities that a scientist wants to remain constant, and he must observe them as carefully as the dependent variables. For example, if we want to measure how much water flow increases when we open a faucet, it is important to make sure that the water pressure (the controlled variable) is held constant. That's because both the water pressure and the opening of a faucet have an impact on how much water flows. If we change both of them at the same time, we can't be sure how much of the change in water flow is because of the faucet opening and how much because of the water pressure. In other words, it would not be a fair test. Most experiments have more than one controlled variable. Some people refer to controlled variables as "constant variables."

In a good experiment, the scientist must be able to **measure** the values for each variable. Weight or mass is an example of a variable that is very easy to measure. However, imagine trying to do an experiment where one of the variables is love. There is no such thing as a "love-meter." You might have a **belief** that someone is in love, but you cannot really be sure, and you would probably have friends that don't agree with you. So, love is not measurable in a scientific sense; therefore, it would be a poor variable to use in an experiment.

It is important for an experiment to be a **fair test**. **You conduct a fair test by making sure that you change one factor at a time while keeping all other conditions the same.**

- For example, let's imagine that we want to measure which is the fastest toy car to coast down a sloping ramp. If we gently release the first car, but give the second car a push start, did we do a fair test of which car was fastest? No! We gave the second car an unfair advantage by pushing it to start. That's not a fair test! The only thing that should change between the two tests is the car; we should start them down the ramp in exactly the same way.
- Let's pretend we're doing an experiment to see if fertilizer makes a plant grow to be larger than a plant that doesn't receive fertilizer. We put seeds of the same kind in three pots with fertilizer and rich soil. But, we run out of soil so we put the seeds without fertilizer in three pots filled with sand. We put all six pots in the same location and water each one with the same amount of water every other day. The plants with soil and fertilizer grow to be much larger than the ones grown in sand without fertilizer. Is that a fair test of whether fertilizer makes a plant grow to be larger? No! We changed two things (type of soil and fertilizer) so we have no idea whether the plants with fertilizer grew to be larger because of the fertilizer or whether the other plants were stunted by being grown in sand. It wasn't a fair test! All of the plants should have been in the same kind of soil.

Examples of Variables

Question	Independent Variable (What I change)	Dependent Variables (What I observe)	Controlled Variables (What I keep the same)
How much water flows through a faucet at different openings?	Water faucet opening (closed, half open, fully open)	Amount of water flowing measured in liters per minute	• The Faucet • Water pressure, or how much the water is "pushing" "Different water pressure might also cause different amounts of water to flow and different faucets may behave differently, so to insure a fair test I want to keep the water pressure and the faucet the same for each faucet opening that I test."
Does heating a cup of water allow it to dissolve more sugar?	Temperature of the water measured in degrees Centigrade	Amount of sugar that dissolves completely measured in grams	• Stirring • Type of sugar "More stirring might also increase the amount of sugar that dissolves and different sugars might dissolve in different amounts, so to insure a fair test I want to keep these variables the same for each cup of water."
Does fertilizer make a plant grow bigger?	Amount of fertilizer measured in grams	• Growth of the plant measured by its height • Growth of the plant measured by the number of leaves • See Measuring Plant Growth for more ways to measure plant growth	• Same type of fertilizer • Same size pot for each plant • Same type of plant in each pot • Same type and amount of soil in each pot • Same amount of water and light • Make measurements of growth for each plant at the same time "The many variables above can each change how fast a plant grows, so to insure a fair test of the fertilizer, each of them must be kept the same for every pot."
Does an electric motor turn faster if you increase the voltage?	Voltage of the electricity measured in volts	Speed of rotation measured in revolutions per minute (RPMs)	• Same motor for every test • The motor should be doing the same work for each test (turning the same wheel, propeller or whatever) "The work that a motor performs has a big impact on its speed, so to insure a fair test I must keep that variable the same."

Time as an Example of an Independent Variable

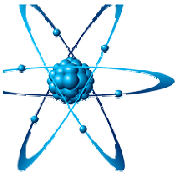
In some experiments, time is what causes the dependent variable to change. The scientist simply starts the process, then observes and records data at regular intervals.

Question	Independent Variable (What I change)	Dependent Variables (What I observe)	Controlled Variables (What I keep the same)
How fast does a candle burn?	Time measured in minutes	Height of candle measured in centimeters at regular intervals of time (for example, every five minutes)	• Use same type of candle for every test • Wind--make sure there is none

The Independent Variable for Surveys and Tests of Different Groups

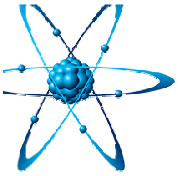
When a scientist performs a test or survey on different groups of people or things, those groups define the independent variable. For example:

Question	Independent Variable (What I change)	Dependent Variables (What I observe)	Controlled Variables (What I keep the same)
Who listens to music the most: teenagers or their parents?	The groups receiving the survey: teenagers or parents	The amount of time that each person listens to music per day measured in hours	Ask the question in exactly the same way to each individual



Variables – More Examples

Question	Independent Variable (What I change)	Dependent Variables (What I observe)	Controlled Variables (What I keep the same)
Is a classroom noisier when the teacher leaves the room?	Teacher location: The teacher is either in the room or not in the room. "The teacher's location is an either/or situation"	Loudness measured in decibels	• Same classroom • Same students • Same time of day
Do bicycle fenders keep the rider dry when riding through a puddle?	Fenders: The bicycle either has fenders or it does not "Many engineering projects have alternative designs with independent variables like this one (with and without fenders)."	The rider either gets wet or does not "Dependent variables can represent either/or situations, too."	• Same type of bike and tires (except for the fenders!) • Riding at the same speed • Same size and depth of puddle



Sample Variables & Hypothesis

Question

How does the voltage of an AA battery change over time when used in low, medium, and high current drain devices?

Hypothesis

If I use a AA battery in any current-draining device, then the voltage of the battery will drop over time. If I perform this test in low, medium, and high current drain devices, then the rate of voltage drop will be slowest in the low current drain device and fastest in the high current drain device.

There are two parts of this hypothesis, and thus two experiments:

- **Experiment #1:** Measure the voltage of fresh AA batteries as they are used in different current drain devices.
- **Experiment #2:** Compare the rate of voltage change between devices with low, medium, and high current drain. The second experiment does not require any more data collection, but it does require looking at the data from experiment #1 in a different way. For experiment #2, graph the data with the voltage on the y-axis and time on the x-axis for each type (low, medium, high) of current drain device.

Variables

Experiment #1:

- Independent Variable: Time (how long each battery operates in a given device)
- Dependent Variable: Voltage

Experimental Group	Controlled Variables for Each Group
Low current drain	Same portable CD player Play the same music track Play at the same volume level
Medium current drain	Identical flashlight Identical light bulb
High current drain	Same camera flash
All groups	Battery size (AA) Constant temperature (A battery works better at a warm temperature.) Battery brand Voltmeter

Experiment #2:

- Independent variable: Type of current drain device (as quantified by low, medium, and high)
- Dependent variable: Voltage (same as experiment #1)
- Controlled variables: Same as outlined in the table above for experiment #1

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Hypothesis and Variables

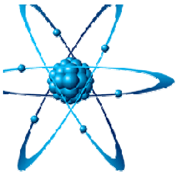
Example Hypotheses

- "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].
- "Raising the temperature of a cup of water [temperature is the independent variable] will increase the amount of sugar that dissolves [the amount of sugar 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]."
- "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 [ ].

Notice that 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.

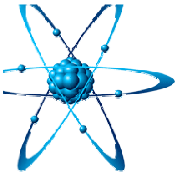


Advanced Topic -- Cause & Effect or Correlation?

In some experiments it is not possible to demonstrate that a change in the independent variable **causes** a change in the dependent variable. Instead one may only be able to show that the independent variable is related to the dependent variable. This relationship is called a **correlation**. One of the most common reasons to see a correlation is that "*intervening* variables are also involved which may give rise to the *appearance* of a possibly direct cause-and-effect relationship, but which upon further investigation turn out to be more directly caused by some other factor" (Wikipedia, 2006).

Advanced Topic -- Is it OK to Disprove Your Hypothesis?

Is all science accomplished using this same method that is taught in schools and emphasized at science fairs? Should you worry if you end up disproving your hypothesis? Actually, the answers are no it's not, and no don't worry if you disprove your hypothesis. Learn more in this essay written by a veteran Science Buddies Adviser, Dr. Bruce Weaver.



Sample Variables & Hypothesis

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Variables

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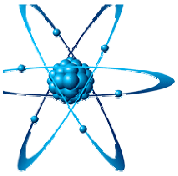
All groups	Battery size (AA) Constant temperature (A battery works better at a warm temperature.) Battery brand Voltmeter

Experiment #2:

- Independent variable: Type of current drain device (as quantified by low, medium, and high)
- Dependent variable: Voltage (same as experiment #1)
- Controlled variables: Same as outlined in the table above for experiment #1



Experimental Procedure

- Write the **experimental procedure** like a step-by-step recipe for your science experiment. A good procedure is so detailed and complete that it lets someone else duplicate your experiment exactly!
- **Repeating a science experiment is an important step** to verify that your results are consistent and not just an accident.
  - For a typical experiment, you should plan to repeat it at least three times (more is better).
  - If you are doing something like growing plants, then you should do the experiment on at least three plants in separate pots (that's the same as doing the experiment three times).
  - If you are doing an experiment that involves testing or surveying different groups, you won't need to repeat the experiment three times, but you will need to test or survey a sufficient number of participants to insure that your results are reliable. You will almost always need many more than three participants!

Now that you have come up with a hypothesis, you need to develop an experimental procedure for testing whether it is true or false.

The first step of designing your experimental procedure involves planning how you will change your independent variable and how you will measure the impact that this change has on the dependent variable. To guarantee a fair test when you are conducting your experiment, you need to make sure that the only thing you change is the independent variable. And, all the controlled variables must remain constant. Only then can you be sure that the change you make to the independent variable actually caused the changes you observe in the dependent variables.

Scientists run experiments more than once to verify that results are consistent. In other words, you must verify that you obtain essentially the same results every time you repeat the experiment with the same value for your independent variable. This insures that the answer to your question is not just an accident. Each time that you perform your experiment is called a **run** or a **trial**. So, your experimental procedure should also specify how many trials you intend to run. Most teachers want you to **repeat your experiment a minimum of three times**. Repeating your experiment more than three times is even better, and doing so may even be required to measure very small changes in some experiments.

In some experiments, you can run the trials all at once. For example, if you are growing plants, you can put three identical plants (or seeds) in three separate pots and that would count as three trials.

In experiments that involve testing or surveying different groups of people, you will not need to repeat the experiment multiple times. However, in order to insure that your results are reliable, you need to test or survey enough people to make sure that your results are reliable. How many participants are enough, what is the ideal sample size?

Every good experiment also **compares** different groups of trials with each other. Such a comparison helps insure that the changes you see when you change the independent variable are in fact caused by the independent variable. There are two types of trial groups: experimental groups and control groups.

The **experimental group** consists of the trials where you change the independent variable. For example, if your question asks whether fertilizer makes a plant grow bigger, then the experimental group consists of all trials in which the plants receive fertilizer.

In many experiments it is important to perform a trial with the independent variable at a special setting for comparison with the other trials. This trial is referred to as a **control group**. The control group consists of all those trials where you leave the independent variable in its natural state. In our example, it would be important to run some trials in which the plants get no fertilizer at all. These trials with no fertilizer provide a basis for comparison, and would insure that any changes you see when you add fertilizer are in fact caused by the fertilizer and not something else.

However, not every experiment is like our fertilizer example. In another kind of experiment, many groups of trials are performed at different values of the independent variable. For example, if your question asks whether an electric motor turns faster if you increase the voltage, you might do an experimental group of three trials at 1.5 volts, another group of three trials at 2.0 volts, three trials at 2.5 volts, and so on. In such an experiment you are comparing the experimental groups to each other, rather than comparing them to a single control group. You must evaluate whether your experiment is more like the fertilizer example, which requires a special control group, or more like the motor example that does not.

Whether or not your experiment has a control group, remember that every experiment has a number of controlled variables. Controlled variables are those variables that we don't want to change while we conduct our experiment, and they must be the same in every trial and every group of trials. In our fertilizer example, we would want to make sure that every trial received the same amount of water, light, and warmth. Even though an experiment measuring the effect of voltage on the motor's speed of rotation may not have a control group, it still has controlled variables: the same motor is used for every trial and the load on the motor (the work it does) is kept the same. A little advance preparation can ensure that your experiment will run smoothly and that you will not encounter any unexpected surprises at the last minute. You will need to prepare a detailed experimental procedure for your experiment so you can ensure consistency from beginning to end. Think about it as writing a recipe for your experiment. This also makes it much easier for someone else to test your experiment if they are interested in seeing how you got your results.

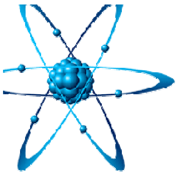
It is important for an experiment to be a **fair test**. You conduct a fair test by making sure that you change one factor at a time while keeping all other conditions the same.

- For example, let's imagine that we want to measure which is the fastest toy car to coast down a sloping ramp. If we gently release the first car, but give the second car a push start, did we do a fair test of which car was fastest? No! We gave the second car an unfair advantage by pushing it to start. That's not a fair test! The only thing that should change between the two tests is the car; we should start them down the ramp in exactly the same way.
- Let's pretend we're doing an experiment to see if fertilizer makes a plant grow to be larger than a plant that doesn't receive fertilizer. We put seeds of the same kind in three pots with fertilizer and rich soil. But, we run out of soil so we put the seeds without fertilizer in three pots filled with sand. We put all six pots in the same location and water each one with the same amount of water every other day. The plants with soil and fertilizer grow to be much larger than the ones grown in sand without fertilizer. Is that a fair test of whether fertilizer makes a plant grow to be larger? No! We changed two things (type of soil and fertilizer) so we have no idea whether the plants with fertilizer grew to be larger because of the fertilizer or whether the other plants were stunted by being grown in sand. It wasn't a fair test! All of the plants should have been in the same kind of soil.
- Conducting a fair test is one of the most important ingredients of doing good, scientifically valuable experiments. To insure that your experiment is a fair test, you must **change only one factor at a time while keeping all other conditions the same**.
- Scientists call the changing factors in an experiment **variables**.

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!

Where will you conduct your experiment? You may need a lot of room for you experiment or you may not be able to move your experiment around from place to place. If you are working with human or animal subjects, you may need a location that is quiet. You will need to think about these limitations before you start your experiment so you can find a location in advance that will meet your needs.



Sample Materials List & Experimental Procedure

Materials List

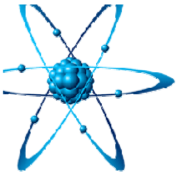
- CD player & a CD (low drain device)
- Three identical flashlights (medium drain device)
- Camera flash (high drain device)
- AA size Duracell and Energizer batteries
- AA size of a "heavy-duty" (non-alkaline) battery (I used Panasonic)
- Voltmeter & a AA battery holder
- Kitchen timer

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.

Experimental Procedure Checklist

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



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