Deering Estate At Cutler

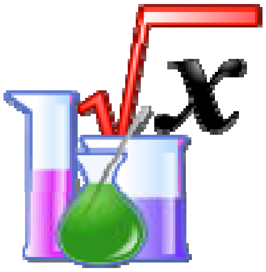
ECO-ACADEMY for Youth and Parent Educators

Learning about the scientific method is almost like saying that you are learning how to learn. You see, the **scientific method** is the way scientists learn and study the world around them. It can be used to study anything from a leaf to a dog to the entire Universe.

Module: Natural Sciences

The Scientific Method

Sunshine State Standards:



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Objectives

- Understand the Scientific Method
- Learn and understand the different steps of the Scientific Method
- Understand the important of the Scientific Method
- Create your own experiment and test your hypothesis using the Scientific Method

Vocabulary

Data- refers to groups of information that represent the qualitative or quantitative attributes of a variable or set of variables.

Deductive reasoning- where facts are determined by combining existing statements

Experiment - are the step in the scientific method that arbitrates between competing models or hypotheses. Experimentation is also used to test existing theories or new hypotheses in order to support them or disprove them. An experiment or test can be carried out using the scientific method to answer a question or investigate a problem. First an observation is made. Then a question is asked, or a problem arises. Next, a hypothesis is formed. Then experiment is used to test that hypothesis. The results are analyzed, a conclusion is drawn, sometimes a theory is formed, and results are communicated through research papers.

Hypothesis- is a proposed explanation for an observable phenomenon.

Inductive reasoning- where facts are determined by repeated observations

Model - is a scientific statement that has some experimental validity or is a scientific concept that is only accurate under **limited situations**. Models do not work or apply under all situations in all environments. They are not universal ideas like a law or theory.

Observation- is either an activity of a living being (such as a human), consisting of receiving knowledge of the outside world through the senses, or the recording of data using scientific instrument. The term may also refer to any data collected during this activity. An observation can also be the way you look at things or when you look at something.

Theory- is a tested and testable concept which is used to explain an occurrence

Law - is a concise verbal or mathematical statement of a relation that expresses a fundamental principle of science, like Newton's law of universal gravitation. A scientific law must always apply under the same conditions, and implies a causal relationship between its elements. The law must be confirmed and broadly agreed upon through the process of inductive reasoning.

Variable- 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.

Background

Reasoning in Science

The basis of the scientific method is asking questions and then trying to come up with the answers. You could ask, "Why do dogs and cats have hair?" One answer might be that it keeps them warm. BOOM! It's the scientific method in action. (OK, settle down.)

START WITH A SIMPLE QUESTION.
WHY DO SPIDERS SPIN WEBS?

YOU MUST ALWAYS OFFER EVIDENCE TO SUPPORT YOUR STATEMENTS.

Questions and Answers

Just about everything starts with a question. Usually, scientists come up with questions by looking at the world around them. "Hey look! What's that?" See that squiggly thing at the end of the sentence? A question has been born.

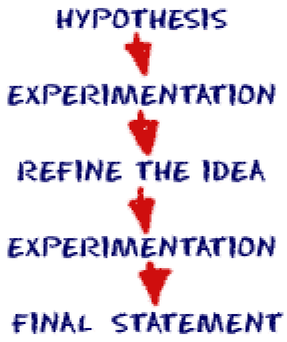
So you've got a scientist. When scientists see something they don't understand they have some huge urge to answer questions and discover new things. It's just one of those scientist personality traits. The trick is that you have to be able to offer some evidence that confirms every answer you give. If you can't test your answer, other scientists can't test it to see if you were right or not.

As more questions are asked, scientists work hard and come up with a bunch of answers. Then it is time to organize. One of the cool things about science is that other scientists can learn things from what has already been established. They don't have to go out and test everything again and again. That's what makes science special: it builds on what has been learned before.

This process allows the world to advance, evolve, and grow. All of today's advancements are based on the achievements of scientists who already did great work. Think about it this way: you will never have to show that water (H_2O) is made up of one oxygen (O) and two hydrogen (H) atoms. Many scientists before you have confirmed that fact. It will be your job as a new scientist to take that knowledge and use it in your new experiments.

Experimental Evidence

Experimental evidence is what makes all of the **observations** and answers in science **valid** (truthful or confirmed). The history of evidence and validations show that the original statements were correct and accurate. It sounds like a simple idea, but it is the basis of all science. Statements must be confirmed with loads of evidence. Enough said.



Scientists start with observations and then make a **hypothesis** (a guess), and then the fun begins. They must then prove their hypothesis with trials and tests that show why their data and results are correct. They must use controls, which are **quantitative** (based on values and figures, not emotions). Science needs both ideas (the hypothesis) and facts (the quantitative results) to move forward. Scientists can then examine their **data** and develop newer ideas. This process will lead to more observation and refinement of hypotheses.

The Whole Process

There are different terms used to describe scientific ideas based on the amount of confirmed experimental evidence.

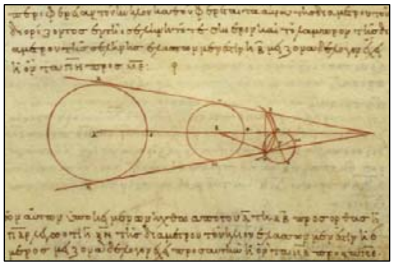
Hypothesis
- a statement that uses a few observations
- an idea based on observations without experimental evidence

Theory
- uses many observations and has loads of experimental evidence
- can be applied to unrelated facts and new relationships
- flexible enough to be modified if new data/evidence introduced

Law
- stands the test of time, often without change
- experimentally confirmed over and over
- can create true predictions for different situations
- has uniformity and is universal

You may also hear about the term "model." A **model** is a scientific statement that has some experimental validity or is a scientific concept that is only accurate under **limited situations**. Models do not work or apply under all situations in all environments. They are not universal ideas like a law or theory.

History



At the time when the two great cultures of Ancient Greece and Ancient Persia were seeking dominance and fighting wars at Thermopylae and Platea, it is easy to forget that these two cultures also had a deep mutual respect, and traded ideas and knowledge.

Unsurprisingly, and fittingly, our history of the scientific method will start here, although we must point out that knowledge knows no boundaries. Whilst Babylonian, Indian and Egyptian astronomers, physicians and mathematicians developed some empirical ideas, the Greeks were the first to develop what we recognize as the scientific method. (*Picture*: work by Aristarchus of Samos trying to measure the distances and sizes of the Moon and the Sun)

Initially, the Ancient Greek philosophers did not believe in empiricism, and saw measurements, such as geometry, as the domain craftsmen and artisans. (*Picture* on right is Plato and Aristotle) Philosophers, such as Plato, believed that all knowledge could be obtained through pure reasoning, and that there was no need to actually go out and measure anything this was called the Deductive Reasoning.

Aristotle, regarded as the father of science, was the first to realize the importance of empirical measurement, believing that knowledge could only be gained by building upon what is already known, this eventually was called the Inductive Reasoning.

Measurement and observation, the foundations upon which science is built, were Aristotle's contribution. He proposed the idea of induction as a tool for gaining knowledge, and understood that abstract thought and reasoning must be supported by real world findings.

He applied his methods to almost everything, from poetry and politics to astronomy and natural history. His 'proto-scientific method' involved making meticulous observations about everything.

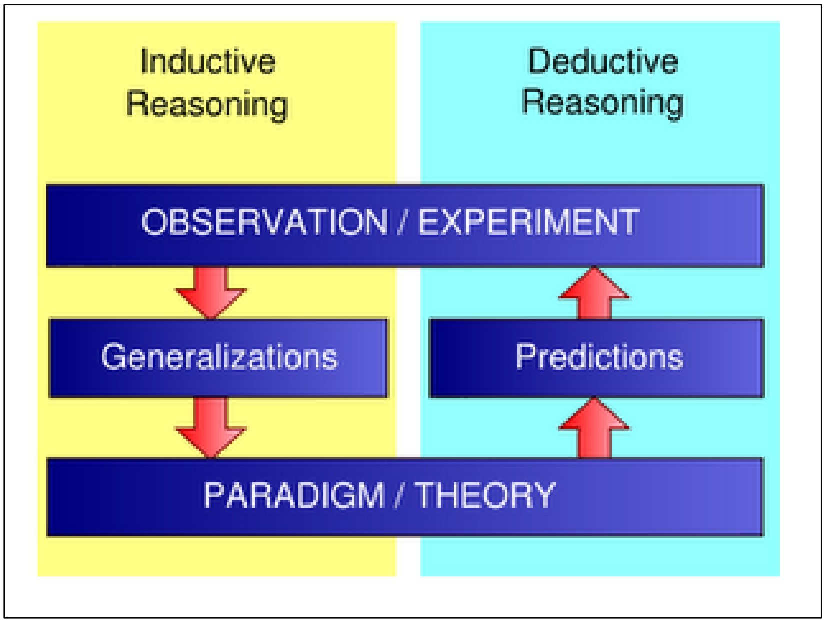
To study the natural world, he scrutinized over 500 species and, in a treatise about politics, he studied the constitutions of 158 Greek city-states, a mammoth undertaking and a direct contrast to Plato, whose idea of a perfect republic was based upon his idea of perfection rather than upon existing systems.

Aristotle's methods can be summed up as follows.

1. Study what others have written about the subject.
2. Look for the general consensus about the subject
3. Perform a systematic study of everything even partially related to the topic.

This is the first sign of a scientific method, with literature reviews, consensus and measurement. The Greeks were the first to subdivide and name branches of science in a recognizable way, including physics, biology, politics, and zoology and, of course, poetry!

In about 200 BC, the famous library at Alexandria saw the first introduction of library cataloguing, essential for any scholar conducting a peer review. (*Picture*: Deductive Reasoning developed by Plato and Inductive Reasoning developed by Aristotle)

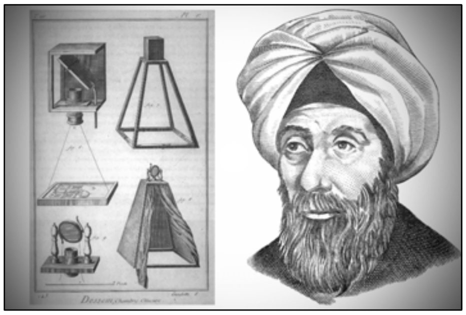


Deductive Reasoning by Plato	***Inductive Reasoning by Aristotle***
An example of a deductive argument: 1. All men are mortal 2. Socrates is a man 3. Therefore, Socrates is mortal	An example of a inductive argument: 1. All of the ice we have examined so far is cold. 2. Therefore, 3. All ice is cold.

THE MUSLIM INFLUENCE ON THE HISTORY OF THE SCIENTIFIC METHOD

The early Islamic ages were a golden age for knowledge, and the history of the scientific method must pay a great deal of respect to some of the brilliant Muslim philosophers of Baghdad and Al-Andalus.

They preserved the knowledge of the Ancient Greeks, including Aristotle, but also added to it, and were the catalyst for the formation of a scientific method recognizable to modern scientists and philosophers.



The first, and possibly greatest Islamic scholar, was **Ibn al-Haytham,** also known as **Alhazen** (*Picture* on left), best known for his wonderful work on light and vision, called ‘The Book of Optics.’ He developed a scientific method very similar to our own:

1. State an explicit problem, based upon observation and experimentation.
2. Test or criticize a hypothesis through experimentation.
3. Interpret the data and come to a conclusion, ideally using mathematics.
4. Publish the findings

Ibn al-Haytham, brilliantly, understood that controlled and systematic experimentation and measurement were essential to discovering new knowledge, built upon existing knowledge.

His other additions were the idea that science is a quest for ultimate truth and that one of the only ways to reach that goal was through skepticism and questioning everything.

Other Muslim scholars further contributed to this scientific method, refining it and preserving it. **Al-Biruni** understood that measuring instruments and human observers were prone to error and bias, so proposed that experiments needed replication, many times, before a ‘common sense’ average was possible.

Al-Rahwi (851 – 934) was the first scholar to use a recognizable peer review process. In his book, Ethics of the Physician, he developed peer review process to ensure that physicians documented their procedures and lay them open for scrutiny. Other physicians would review the processes and make a decision in cases of suspected malpractice.

Abu Jābir, known as Geber (721 - 815), an Islamic scientist often referred to as the father of chemistry, was the first scholar to introduce controlled experiments, and dragged alchemy away from the world of superstition into one of empirical measurement. (*picture* on the left)

Ibn Sina (Avicenna), one of the titans in the history of science, proposed that there were two ways of arriving at the first principles of science, through induction and experimentation. Only through these methods could the first principles needed for deduction be discovered

Other Islamic scholars contributed the idea of consensus in science as a means of filtering out fringe science and allowing open reviews. These contributions to the scientific method, and to the tools required to follow them, made this into an Islamic Golden Age of science.

However, with the decline in the Islamic Houses of Knowledge, the history of the scientific method passed into Europe and the Renaissance.

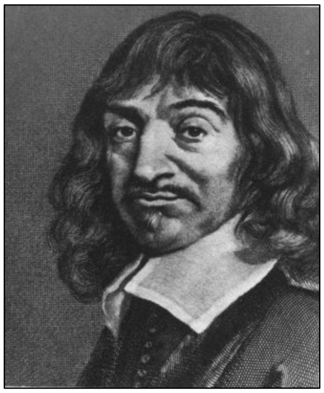
THE RENAISSANCE AND THE HISTORY OF THE SCIENTIFIC METHOD

The renaissance was another turning point for the scientific method, where European scholars took the knowledge of the Greeks and the Muslims, and added to it.

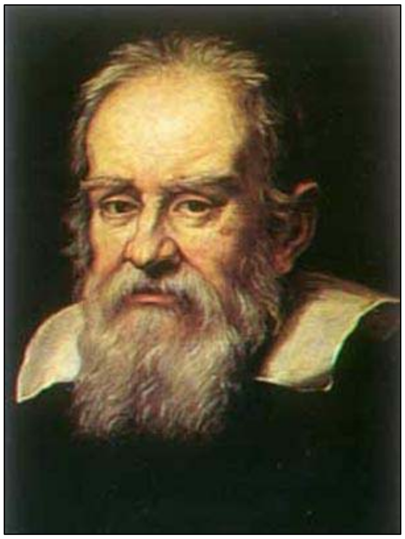
Again, it is impossible to list every single scholar, but there are some names that stand out in any narration of the history of the scientific method.

Roger Bacon (1214 - 1294) was one of the earliest European scholars to refine the scientific methods. He developed the idea of making observations, hypothesizing and then experimenting to test the hypothesis. In addition, he documented his experiments meticulously so that other scientists could repeat his experiments and verify his results.

Francis Bacon (1561 - 1626), was one of the greatest movers behind the development of the scientific method. He reiterated the importance of induction as part of the scientific method, believing that all scientific discovery should proceed through a process of observation, experimentation, analysis and inductive reasoning, to apply the findings to the universe as a whole. He also believed that experimental evidence could be used to eliminate conflicting theories and move closer to the truth.



The great philosopher and mathematician **Descartes** (1596 – 1650), by contrast, firmly believed that the universe was like a huge machine. Therefore, if you understood the basic laws of the universe, you could deduce how anything will act.



Galileo (1564 – 1642) is generally remembered for his famous gravity experiment, but he also contributed greatly to the scientific method. Certainly, his methodology shaped physics and other fields relying upon mathematical theorems. His methods, which were the origins of the split between science and religion, included a standardization of measurements allowing experimental results to be checked anywhere. Galileo used a heavily inductive scientific method because he understood that no empirical evidence could perfectly match theoretical predictions. He believed that it would be impossible for an experimenter to take into account every single variable. In the world of physics, for example, Galileo theorized that mass had no effect upon gravitational acceleration. No experiment could ever hope to measure this perfectly, because of air resistance, friction and inaccuracies with timing devices and methods.

This period, covering the sixteenth and seventeenth centuries, is often referred to as the Scientific Revolution, and threw out some more elements required for the scientific method. The Royal Society was set up, in 1660, providing a panel of experts to advise and guide, as well as oversee the spreading of information, establishing a journal to aid this process. This body ruled that experimental evidence always supersedes theoretical evidence, one of the foundations of modern science. Naturally, the installing of a panel of experts and the founding of journals also led to genuine peer review, a process adapted from the Muslim practices. (*Picture*: The Royal Society in London)

The Scientific Revolution reached its zenith with **Isaac Newton** (*picture* on right), who made perhaps the greatest contribution to the history of the scientific method. He was the first to really understand that the scientific method needed both deduction and induction.

The History of the Scientific Method and the Twentieth Century

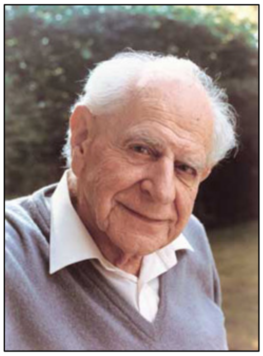
The scientific method, as developed by Bacon and Newton, continued to be the main driver of scientific discovery for three centuries. However, their ideas were based at a time where most scientists were polymaths, working in many scientific fields and also understanding philosophy and theology.

Science gradually began to move away from those areas and developed into a separate area of study. In addition, the increasing complexity of science and the increase in both breadth and depth made it impossible for a scholar to work across disciplines.

As science began to split into chemistry, physics, biology and the proto-scientific psychology, the history of the scientific method became much more complex.

Physicists could remain true to the Baconian inductive methods, but psychologists began to find this increasingly difficult when dealing with the extreme variability of the human mind and man-made constructs.

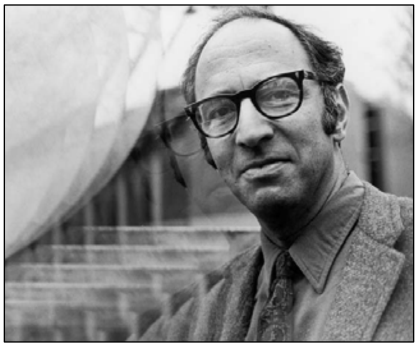
As a result, the Twentieth Century saw a huge change in the scientific method as philosophers of science attempted to address this. Probably the most famous of these was Karl Popper, who understood the limitations of the old scientific ways.



Popper’s contribution to the history of the Scientific Method

Documenting Karl Popper’s contribution to the history of the scientific method is significant. Popper’s main point of attack was establishing that science was not infallible. Well-established scientific disciplines often followed the wrong path and generated incorrect theories.

Popper postulated that science advances through a process of “conjecture and refutations;” that a theoretical scientist would develop a theory and an empirical scientist would attempt to test it to destruction. For this to happen, the theory had to be ‘falsifiable’. If the theory could not be properly tested by science, then it could not be scientific.



Kuhn’s Contribution to the History of the Scientific Method

Thomas Kuhn was the next of the Twentieth Century to add to the history of the scientific method, by introducing the idea of paradigms.

This particular idea was built around the idea that science developed conflicting theories about how everything worked. Experimentation would lead to one of these theories becoming dominant and accepted by the scientific community. Kuhn christened this a ‘scientific paradigm.’

He believed that a group of scientists would hold to a particular paradigm, often very stubbornly, until the body of evidence became so great that a ‘paradigm shift’ became unavoidable.

Scientists would then adopt the new paradigm and begin working within its constraints, although two paradigms were not necessarily mutually exclusive.

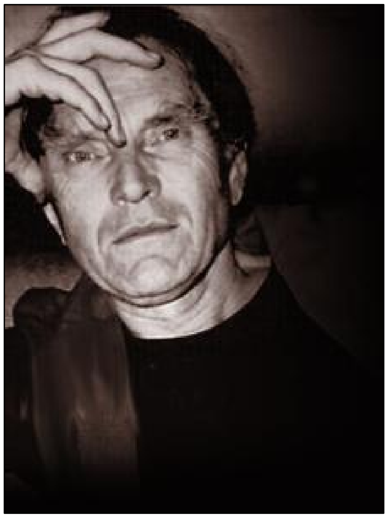
For example, some physicists believed that electrons were particles; others believed that electrons were waves. Eventually, physicists found that they acted as both and so the paradigms overlapped.

Now, of course, quantum physics is opening up new definitions and the paradigm is shifting again.

Psychology provides another perfect example of paradigm shift, in the form of the nature vs. nurture debate. Some psychologists argued that all behavior was inbuilt and dictated at birth, whilst others believed in the Tabula Rasa, a clean slate mind, where all programming was the result of upbringing, environmental stimuli and education.

Currently, the current paradigm is that both have an important influence, and psychology and physiology seem to support this paradigm.

Feyerabend’s Contribution to tehistory of the scientific method

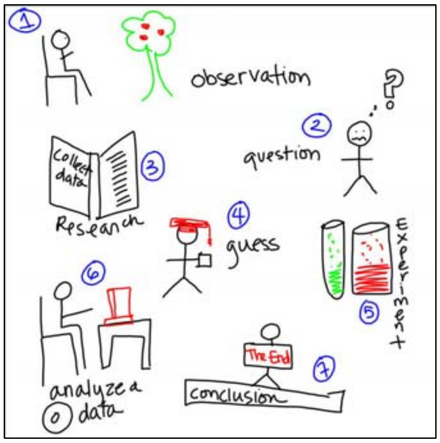


The last of the three great philosophers behind the history of the scientific method is Paul Feyerabend, the scientific anarchist. As Popper had realized that science had split into many differing disciplines, Feyerabend realized that these disciplines had become too complex to define by one overarching method. In fact, Feyerabend believed that trying to force all scientific disciplines to follow a set of rules actually hampered science, creating false restrictions and barriers to progress. His famous philosophy of ‘Anything Goes’ was an attempt to address this, by arguing that scientists should not be influenced by ‘arcane’ philosophies.

He pointed to physics as an example of this, lamenting the abundance of physicists who had no grasp of philosophy, arguing that if they did not understand it, how could they be constrained by it?

His strongest argument against the scientific method was that, historically, many great discoveries would not have been made if constrained by the strict limitations of the scientific method, pointing to the work of Galileo and Copernicus. He believed that scientists often had to make up rules as they went along, adapting their methods to tackle new discoveries that could not be examined without breaking the established rules.

He pointed out that scientific discovery progressed unevenly and that the greatest scientific leaps ignored the scientific method. If Copernicus, Darwin, Einstein or Wegener had stuck with the strict scientific method, they would never have published their theories and instead they would have become stuck in an endless loop of observation and experiment. They would have been consigned to making small scientific leaps without ever gaining enough momentum and evidence to propose a grand and sweeping theory.



Elements of the Scientific Method

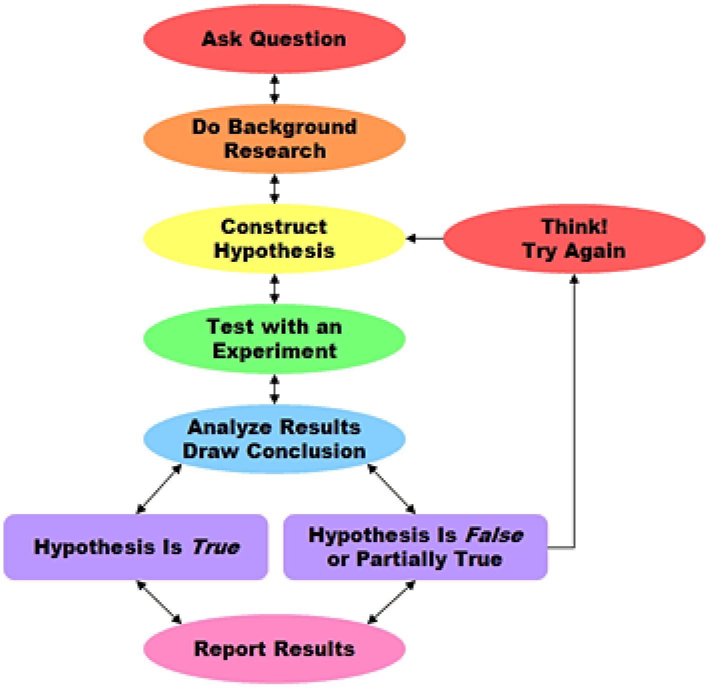
The scientific method is the process by which scientists, collectively and over time, endeavor to construct an accurate (that is, reliable, consistent and non-arbitrary) representation of the world.

Recognizing that personal and cultural beliefs influence both our perceptions and our interpretations of natural phenomena, we aim through the use of standard procedures and criteria to minimize those influences when developing a theory. As a famous scientist once said, "Smart people (like smart lawyers) can come up with very good explanations for mistaken points of view." In summary, the scientific method attempts to minimize the influence of bias or prejudice in the experimenter when testing a hypothesis or a theory.

Scientific method is not a recipe: it requires intelligence, imagination, and creativity. It is also an ongoing cycle, constantly developing more useful, accurate and comprehensive models and methods.

Key Info

- The Scientific Method is a way to ask and answer scientific questions by making observations and doing experiment.
- The steps of the scientific method are to:
  1. ask a question
  2. do background research
  3. construct a hypothesis
  4. test your hypothesis by doing an experiment
  5. analyze your data and draw a conclusion
  6. communicate your results
- It is important for your experiment to be a fair test. A "fair test" occurs when you change only one factor (variable) and keep all the other conditions the same.



The scientific method is a process for experimentation that is used to explore observations and answer questions. Scientists use the scientific method 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.

Just as it does for a professional scientist, the scientific method will help you to focus your science project question, construct a hypothesis, design, execute, and evaluate your experiment.

The scientific method, as defined by various scientists and philosophers, has a fairly rigorous structure that should be followed by Martyn Shuttleworth (2009)

In reality, apart from a few strictly defined physical sciences, most scientific disciplines have to bend and adapt these rules, especially sciences involving the unpredictability of natural organisms and humans.

In many ways, it is not always important to know the exact scientific method, to the letter, but any scientist should have a good understanding of the underlying principles.

In many ways, if you are going to bend and adapt the rules, you need to understand the rules in the first place.

Steps of the Scientific Method

- **Ask a Question:** The scientific method starts when you ask a question about something that you observe: How, What, When, Who, Which, Why, or Where?

And, 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 in putting together a plan for answering your question, you want to be a savvy scientist using library and Internet research to help you find the best way to do things and insure that you don't repeat mistakes from the past.

- **Construct a Hypothesis:** A hypothesis is an educated guess about how things work:
  "If _____*[I do this]* _____, then _____*[this]*_____ will happen."

You must state your hypothesis in a way that you can easily measure, and of course, your hypothesis should be constructed 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. It is important for your experiment to be a fair test. You conduct a fair test by making sure that you change only one factor at a time while keeping all other conditions the same.

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, you collect your measurements and analyze them to see if your hypothesis is true or false.

Scientists often find that their hypothesis was false, and in such cases they will construct a new hypothesis starting the entire process of the scientific method over again. Even if they find that their hypothesis was true, they may want to test it again in a new way.

- **Communicate Your Results:** To complete your science project you will communicate your results to others in a final report and/or a display board. Professional scientists do almost exactly the same thing by publishing their final report in a scientific journal or by presenting their results on a poster at a scientific meeting.

Even though we show the scientific method as a series of steps, keep in mind that new information or thinking might cause a scientist to back up and repeat steps at any point during the process. A process like the scientific method that involves such backing up and repeating is called an ***iterative process***.

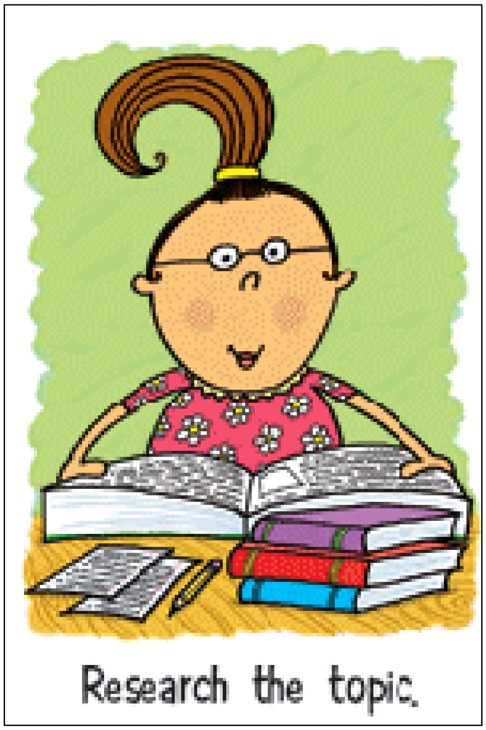
Throughout the process of doing your science project, you should keep a journal containing all of your important ideas and information. This journal is called a ***laboratory notebook***.

It is often said in science that theories can never be proved, only disproved. There is always the possibility that a new observation or a new experiment will conflict with a long-standing theory.

Asking a Question

The question that you select for your science project is the cornerstone of your work. The research and experiment you will be conducting all revolve around finding an answer to the question you are posing. It is important to select a question that is going to be interesting to work on for a long period of time and a question that is specific enough to allow you to find the answer with an experiment. A scientific question usually starts with: How, What, When, Who, Which, Why, or Where.

Research or Literature Review



Research is an often-misused term, its usage in everyday language very different from the strict scientific meaning.

In the field of science, it is important to move away from the looser meaning and use it only in its proper context. Scientific research adheres to a set of strict protocols and long established structures.

Often, we will talk about conducting internet research or say that we are researching in the library. In everyday language, it is perfectly correct grammatically, but in science, it gives a misleading impression. The correct and most common term used in science is that we are conducting a ***literature review***.

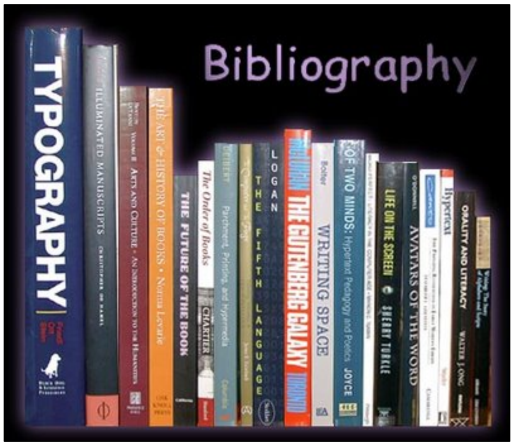
Background research is necessary so that you know how to design and understand your experiment. To make a background research plan -- a roadmap of the research questions you need to answer -- follow these steps:

1. Identify the keywords in the question for your science project. Brainstorm additional keywords and concepts. Use a table with the "question words" (why, how, who, what, when, where) to generate research questions from your keywords.
2. Add to your background research plan a list of mathematical formulas or equations (if any) that you will need to describe the results of your experiment.
3. You should also plan to do background research on the history of similar experiments or inventions.
4. Network with other people with more experience than yourself.

Why the need for background research?

So that you can design an experiment, you need to research what techniques and equipment might be best for investigating your topic. Rather than starting from scratch, savvy investigators want to use their library and Internet research to help them find the best way to do things. You want to learn from the experience of others rather than blunder around and repeat their mistakes. A scientist named Mike Kalish put it humorously like this: "A year in the lab can save you a day in the library."

Bibliography



A bibliography is a listing of the books, magazines, and Internet sources that you use in designing, carrying out, and understanding your science project. But, you develop a bibliography only after first preparing a background research plan -- a roadmap of the research questions you need to answer. Before you compose your bibliography, you will need to develop your background research plan.

With your background research plan in hand, you will find sources of information that will help you with your science project. As you find this information it will be important for you to write down where the sources are from. You can use the Bibliography Worksheet to help you, just print out a few copies and take them with you to the library. As you find a source, write in all of the necessary information. This way, when you are typing your bibliography you won't need to go back to the library and find any missing information. The more information you write down about your source, the easier it will be for you to find if you want to read it again.

When you are writing your report, you will use the sources in your bibliography to remind you of different facts and background information you used for your science fair project. Each time you use some information from a source, you will need to cite the source that it came from. To cite a source, simply put the author's name and the date of the publication in parentheses (Author, date) in your text. If the person reading your report wants to find the information and read more about it, they can look up the reference in your bibliography for more detail about the source. That is why each source you use must be listed in a detailed bibliography with enough information for someone to go and find it by themselves.

Your bibliography should include a minimum of three written sources of information about your topic from books, encyclopedias, and periodicals. You may have additional information from the Web if appropriate.

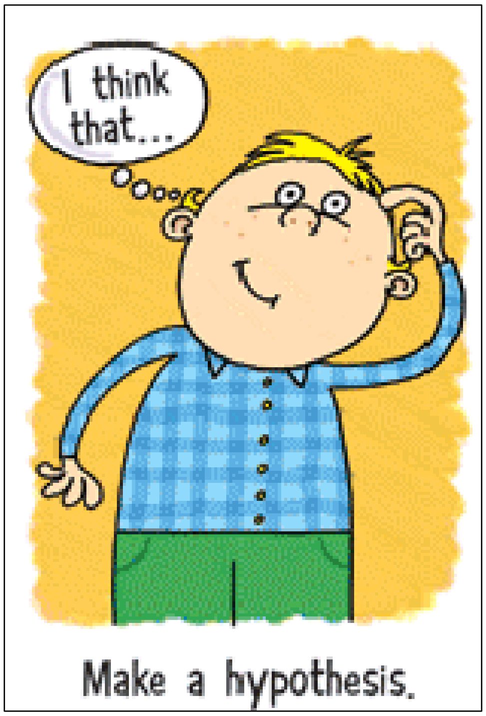
Examples of Bibliography Formats

There are standards for documenting sources of information in research papers. Even though different journals may use a slightly different format for the bibliography, they all contain the same basic information. The most basic information that each reference should have is the author's name, the title, the date, and the source.

Different types of sources have different formatting in the bibliography. In American schools, the two most commonly used guidelines for this formatting are published by the

MLA (Modern Language Association) and the APA (American Psychological Association).

Hypothesis



After having thoroughly researched your question, you should have some educated guess about how things work. This educated guess about the answer to your question is called the hypothesis.

The hypothesis must be worded so that it can be tested in your experiment. Do this by expressing the hypothesis using your independent variable (the variable you change during your experiment) and your dependent variable (the variable you observe-changes in the dependent variable depend on changes in the independent variable). In fact, many hypotheses are stated exactly like this: "If a particular independent variable is changed, then there is also a change in a certain dependent variable."

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.

Plan the Experiment

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 ensure a fair test, a good experiment has only one independent variable. As the scientist changes the independent variable, he or she **observes** what happens.

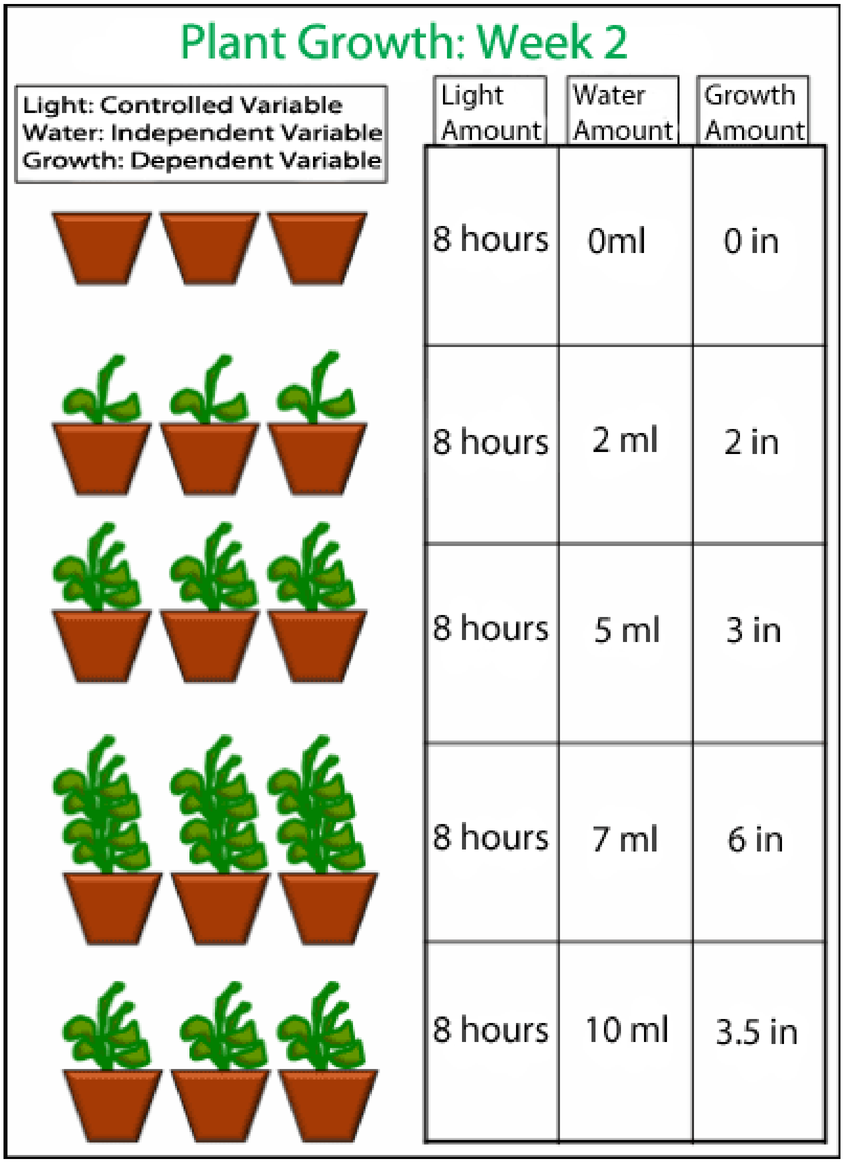
The scientist focuses his or her observations on the **dependent variable** to see how it responds to the change made to the independent variable. The new value of the dependent variable is caused by and depends on the value of the independent variable.

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.

Example of variables in an experiment’

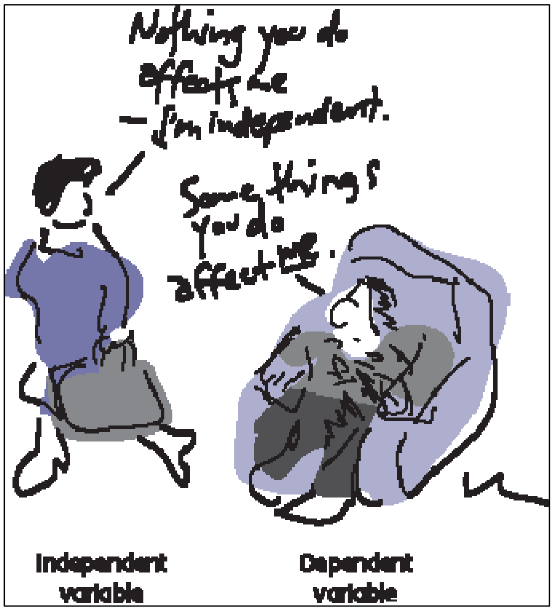


Plant Growth: Week 2

Light: Controlled Variable
Water: Independent Variable
Growth: Dependent Variable

Light Amount	Water Amount	Growth Amount
8 hours	0ml	0 in
8 hours	2 ml	2 in
8 hours	5 ml	3 in
8 hours	7 ml	6 in
8 hours	10 ml	3.5 in

Experimental Procedure



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.

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 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.

Materials lists

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 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

Conducting an experiment

Preparations

With your detailed experimental procedure in hand, you are almost ready to start your science experiment. But before you begin there are still a few more things to do:

- **Know what to do.** Read and understand your experimental procedure. Are all of the necessary steps written down? Do you have any questions about how to do any of the steps?
- **Get a laboratory notebook** for taking notes and collecting data (see Data Table below).
- **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 long hair that needs to be pulled back out of your face? Will you need to be near a fire extinguisher?

Data Table

Prepare a **data table** in your laboratory notebook to help you collect your data. A data table will ensure that you are consistent in recording your data and will make it easier to analyze your results once you have finished your experiment.

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

It is very important to take very detailed notes as you conduct your experiments. In addition to your data, record your **observations** as you perform the experiment. Write down any problems that occur, anything you do that is different than 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.

We suggest that you keep a laboratory notebook so that all your information is kept in one place (don't use loose-leaf notebooks, you want to make sure all your information stays together). The data that you record now will be the basis for your science project final report and your conclusions so capture everything in your **laboratory notebook**, including successes, failures, and accidents.

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.

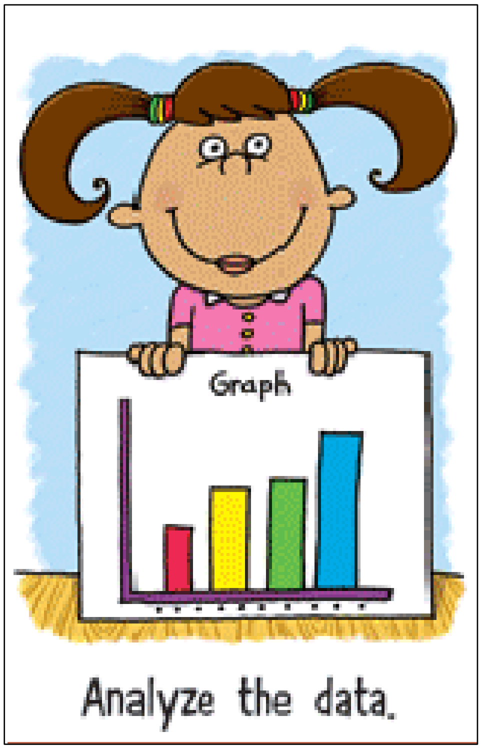
Remember to use numerical measurements as much as possible. If your experiment also has qualitative data (not numerical), then take a photo or draw a picture of what happens.

Be as exact as possible about the way you conduct your experiment, especially in following your experimental procedure, 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.

In fact, it's a good idea to do a quick **preliminary run** of your experiment. 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 kids.

Analyzing Data



Take some time to carefully 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?

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

Calculations and Summarizing Data

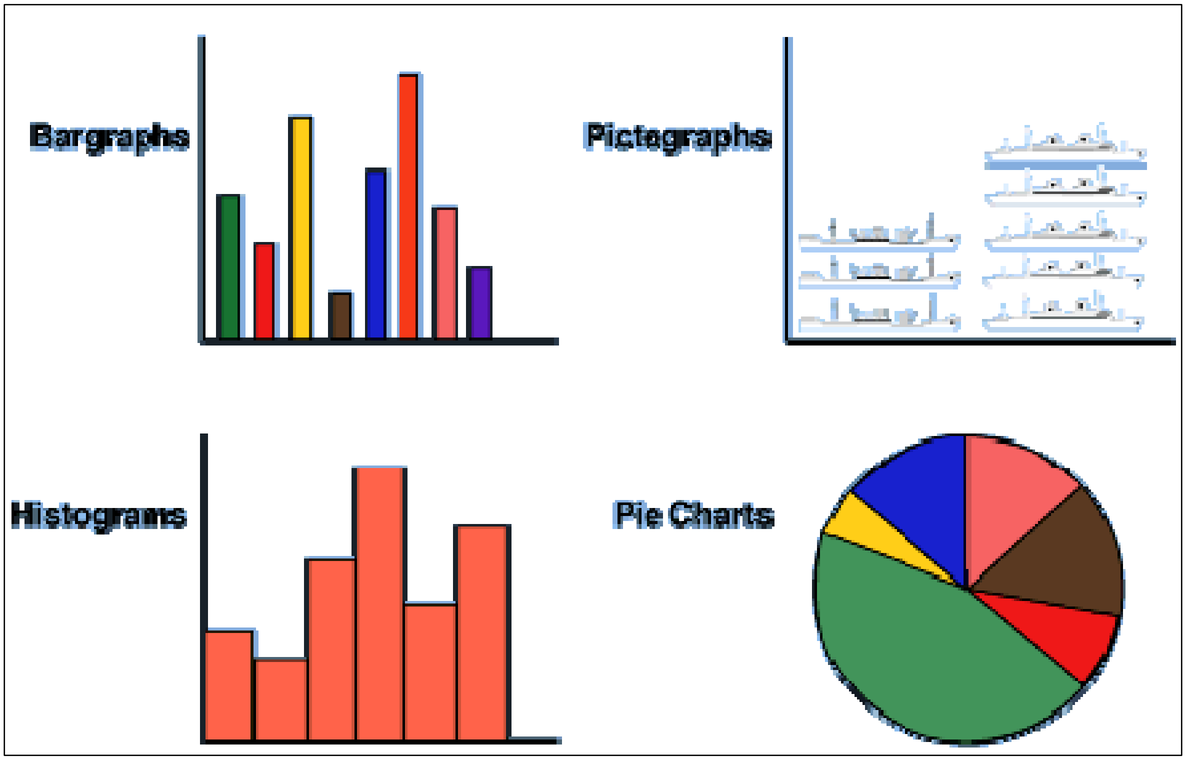
Often, you will need to perform calculations on your raw data in order to get the results from which you will generate a conclusion. A spreadsheet program such as Microsoft Excel may be a good way to perform such calculations, and then later the spreadsheet can be used to display the results. Be sure 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 such as ratios, percentages, or error and significance for really advanced students? Or, is it better to display your data as individual data points?

Do any calculations that are necessary for you to analyze and understand the data from your experiment.

- Use calculations from known formulas that describe the relationships you are testing. (F = MA , V = IR or E = MC2)
- Pay careful attention because you may need to convert some of your units to do your calculation correctly. All of the units for a measurement should be of the same scale– (keep L with L and mL with mL, do not mix L with mL!)

Graphs



Graphs are often an excellent way to display your results. In fact, most good science fair projects have at least one graph.

For any type of graph:

- Generally, you should place your independent variable on the x-axis of your graph and the dependent variable on the y-axis.
- Be sure to label the axes of your graph— don't forget to include the units of measurement (grams, centimeters, liters, etc.).
- If you have more than one set of data, show each series in a different color or symbol and include a legend with clear labels.

Different types of graphs are appropriate for different experiments. These are just a few of the possible types of graphs:

A **bar graph** might be appropriate for comparing different trials or different experimental groups. It also may be a good choice if your independent variable is not numerical.

A **time-series** plot can be used if your dependent variable is numerical and your independent variable is time.

An **xy-line graph** shows the relationship between your dependent and independent variables when both are numerical and the dependent variable is a function of the independent variable.

A **scatter plot** might be the proper graph if you're trying to show how two variables may be related to one another.

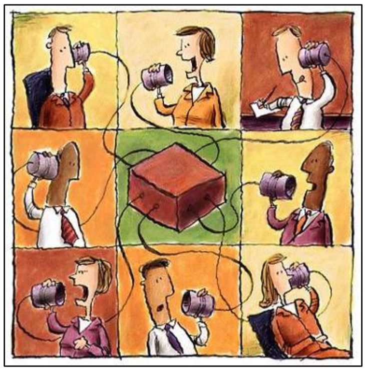
Conclusion

Your conclusions will summarize whether or not your science fair project results support or contradict your original hypothesis. You may want to include key facts from your background research to help explain your results. Do your results suggest a relationship between the independent and dependent variable?

If Your Results Show that Your Hypothesis is False

If the results of your science experiment did not support your hypothesis, don't change or manipulate your results to fit your original hypothesis, simply explain why things did not go as expected. Professional scientists commonly find that results do not support their hypothesis, and they use those unexpected results as the first step in constructing a new hypothesis. If you think you need additional experimentation, describe what you think should happen next.

Scientific research is an ongoing process, and by discovering that your hypothesis is not true, you have already made huge advances in your learning that will lead you to ask more questions that lead to new experiments. Science fair judges do not care about whether you prove or disprove your hypothesis; they care how much you learned.



Communicate Your Results

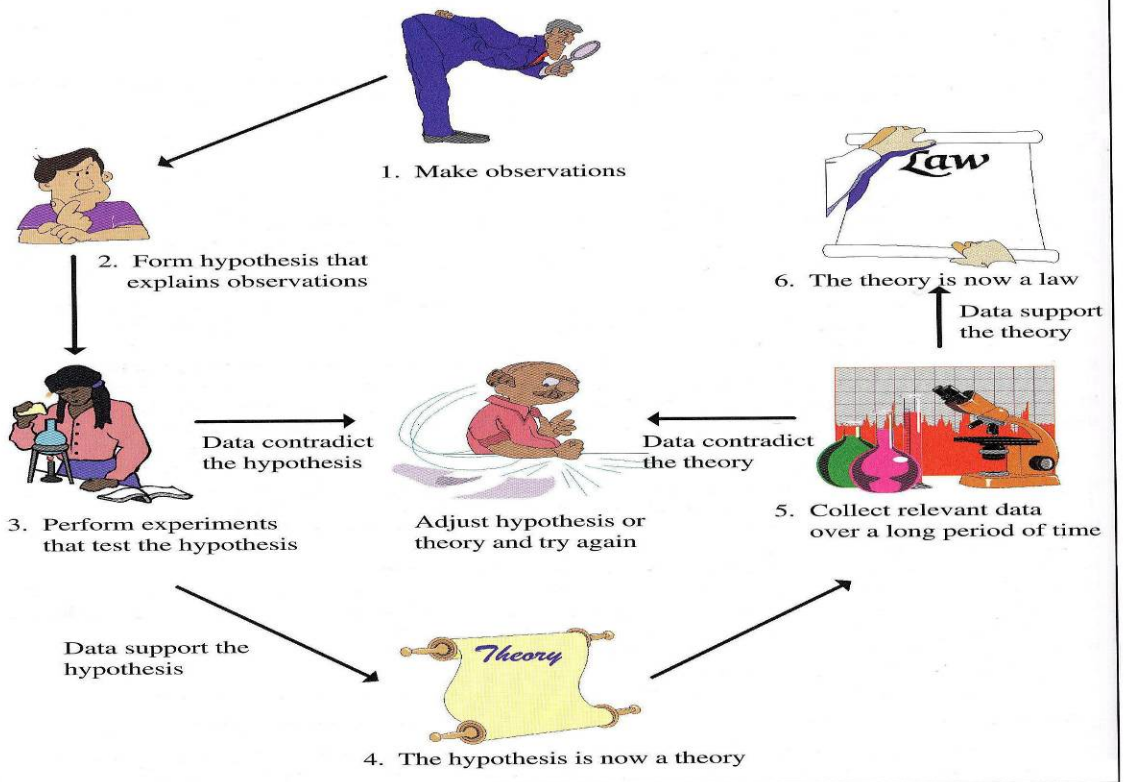
To complete your science fair project you will communicate your results to others in a final report and/or a display board. Professional scientists do almost exactly the same thing by publishing their final report in a scientific journal or by presenting their results on a poster at a scientific meeting.

Final report includes:

- Title page.
- Abstract.
- Table of contents.
- Question, variables, and hypothesis.
- Background research (your Research Paper).
- Materials list.
- Experimental procedure.
- Data analysis and discussion (including data table and graph(s)).
- Conclusions.
- Ideas for future research (for some projects only).
- Acknowledgements.
- Bibliography.

Summary

FIGURE 2.2
The Scientific Method



Activity: Slime Lab

Summary: Students will design their own experiment making slime. They are given a certain amount of materials to make the slime but no procedures or concentrations of materials. This lab works great for discovery.

Duration: 2 hours

Objectives:

- Students will be able to design their own experiment to make slime.
- Students will be able to use the scientific method to test their hypothesis.
- Students will be able to create a pie chart of their results**.**

Materials

- Meter stick: 1 per group
- Stirring rods: 1 per group (wooden sticks or fingers work good)
- 11 beakers, 10 medium size, and one 500 ml
- Paper or plastic cups, 1 per group
- Graduated cylinders, 1 per group and one per beaker
- Glue (Elmer works good) *large container can be bought from home depot.*
- Water
- Food coloring
- Borax detergent

Lab Setup:

First make the borax solution. Mix 1 grams of borax in 500 ml of water. Then pour the solution into 5 beakers of 200 ml for easy access by the students. Second, pour the glue from the large container into cups for each lab group. 100 ml is plenty. Third, pour water into 5 beakers of 200 ml. Place the food-coloring bottle near the borax solution.

Place two cups at each lab station, one cup with glue and one empty cup. Place one large graduated cylinder at each station. Place the borax solution and the water on a desk in an easily accessible and high traffic area of the room. Try to keep all solution near the sink helps with clean up. Place a graduated cylinder next to each beaker.

Procedures:

1. Group students as lab partners. Tell students to do all measuring on top of the tables. Students may not carry the graduated cylinders or beaker around the room. Students perform all work on top of tables or counters. If students get materials on the floor must clean it up immediately.
2. Students conduct the lab by measuring the glue, borax solution and water solutions with graduated cylinders. Students need to fill in their handout with their measurements. Each drop of food coloring counts as a milliliter. Students then stir their mixture. Discourage students to not use their hands for stirring.
3. Students probably will not have a good mixture or stretchable slime. They can get more materials to add to their current mixture but not start over. They fill in their new additions of ml in Attempt 2 and Attempt 3.
4. 30 minutes before the end of the period, stop the additions of materials. This is when students use the stir rod to stretch their slime vertically, using a meter stick to measure the distance. Students record their length into the first row of the data table. Wait for all students to finish measuring.
5. Students then share their lengths, team name and display their slime. Students then infer if the slime is solid, liquid or somewhere in between and infer the viscosity of the slime. High viscosity pours very slowly.
6. The team with the longest stretching slime shares their ml of materials used to make the slime. Students then write in their conclusion. The go further can be finished in class or as homework. Clean up the lab. Adding dry borax will make the slime solid and may possibly bounce.

Evaluation:

The problem statement, hypothesis, ingredients are not worth points. Quesitions 1-18 are worth 2 points each. Total of 36 points. A complete data table is worth 2 points. The pie chart is worth 2 points with the labels and correct values are 1 point each. This assignment is worth of a total of 40 points.

Slime Lab Worksheet

Name: ____

Date: ____

You are going to attempt to make slime. All you have is the materials need to make it. You have to determine first the correct order to add the materials and second the percent composition (how much) of each material. Your group is in competition with the other lab groups to see if they can make the most stretchable slime. Each lab group will come up with their own team name for the competition.

Team Name: ______________________________________

Problem Statement:

____

Hypothesis

____

____

Ingredients

_________________________ _________________________

_________________________ _________________________

Procedures: Attempt 1

1. __________ ml of glue poured into your cup
2. __________ ml of water poured into your cup
3. __________ ml of Borax solution poured into your cup
4. __________ drops of foods coloring poured into your cup. Each drop will count as one ml
5. __________ number of minutes you stirred your mixture

Attempt 2

You added to your mixture

____

Attempt 3

You added to your mixture

____

6. Add up all the ml of the glue added to your mixture ___________________________

7. Add up all the ml of water added to your mixture _____________________________

8. Add up all the ml of borax solution added to your mixture ______________________

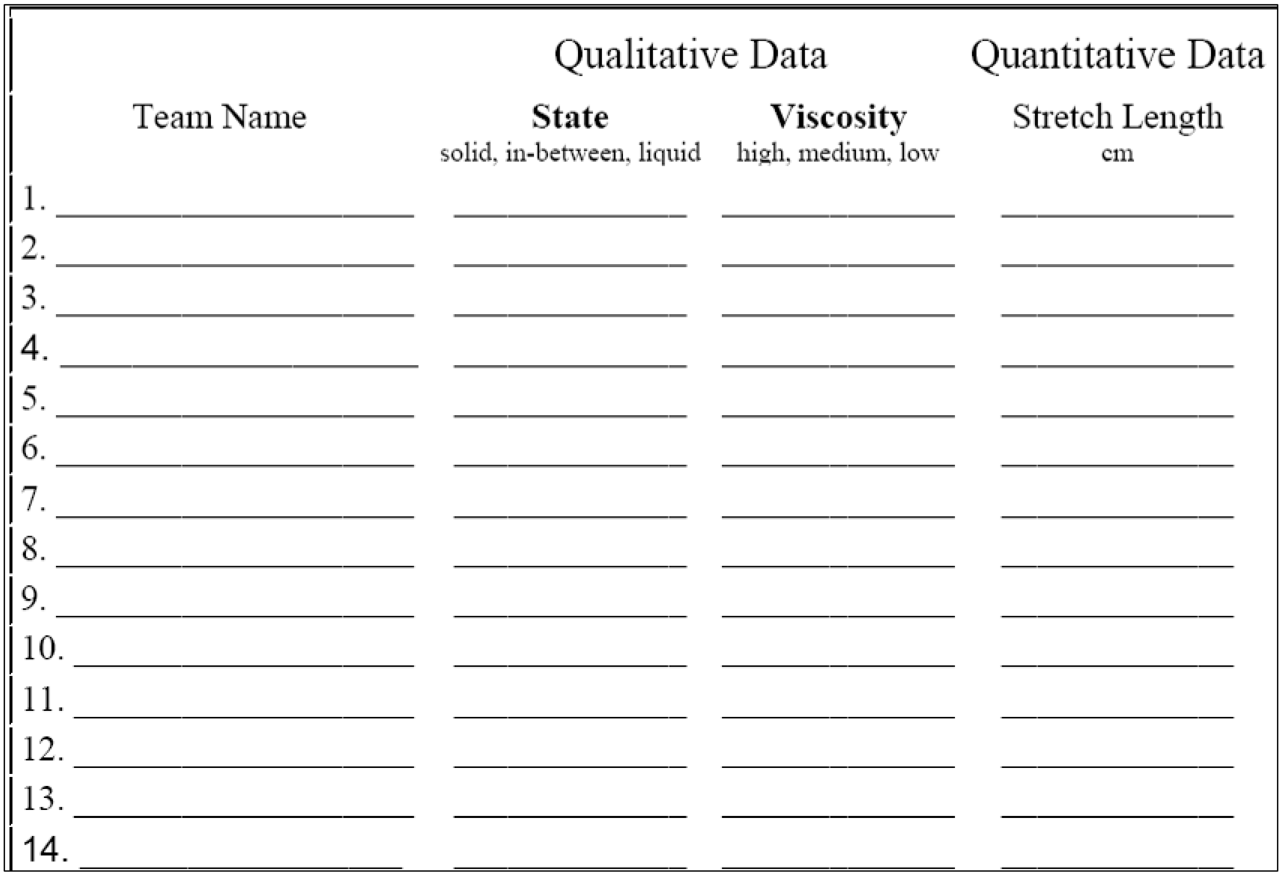
9. Add up all the ml of food coloring added to your mixture _______________________

10. Total ml in your mixture ____

11. What is the % composition of materials for your mixture?

_______ % of glue _______ % of water _______ % of borax _______ % of coloring

Experimental Data:



	Qualitative Data		Quantitative Data
Team Name	**State** solid, in-between, liquid	**Viscosity** high, medium, low	Stretch Length cm
1. ____________________	______________	______________	______________
2. ____________________	______________	______________	______________
3. ____________________	______________	______________	______________
4. ____________________	______________	______________	______________
5. ____________________	______________	______________	______________
6. ____________________	______________	______________	______________
7. ____________________	______________	______________	______________
8. ____________________	______________	______________	______________
9. ____________________	______________	______________	______________
10. ___________________	______________	______________	______________
11. ___________________	______________	______________	______________
12. ___________________	______________	______________	______________
13. ___________________	______________	______________	______________
14. ___________________	______________	______________	______________

Analysis

12. Which team's slime could be stretched the longest? ______________________

ml of glue used: __________ ml of water used:__________

ml of borax used: __________ ml of color used: __________

13. Total ml in the longest stretching mixture: _______________________________

14. What % composition of materials did the longest stretching team have?

_______ % of glue _______ % of water _______ % of borax _______ % of coloring

15. Conclusion

____

Go Further:

16. Which team's slime had the highest viscosity? ____________________________

17. Guess what % composition of materials would create the highest viscosity?

_______ % of glue _______ % of water _______ % of borax _______ % of coloring

18. What ingredient caused their slime to have the highest viscosity?

____

Graphing: Create a pie chart of percentage used in question 14. Please label.

With teacher's permission, now weight 0.5 grams of dry borax on a scale and put it into your mixture. Stir until your slime completely solidifies. Now drop your slime from one meter onto your table and measure the height of the bounce with a meter stick.

Activity: The Fun of Scientific Investigations

Duration: 2 hours

Materials:

- two eggs per pair of students, one raw, one hard-boiled, plus a couple extras for eggs broken extra early
- permanent markers--about 5

Procedure:

1. Query the Egg: You have just been given two eggs. One of your eggs is fresh and one is hard-boiled. Choose one of the eggs and put a mark on it. Do you think the marked egg is (Circle one) Raw Hard-boiled
2. Now, do a scientific investigation and discover all the ways your two eggs differ that could be used to tell any hard-boiled egg from any raw one. (That means that size, shape, color, specks, etc.,. can't be listed, as, if you write that the small one is hard-boiled, it means that all small eggs are hard-boiled.) It might help if you pretend that your dad is going to make cookies and that your little brother mixed up the hard-boiled eggs in the refrigerator and you need to find all the hard-boiled eggs and all the raw ones. (No, you may not break the eggs to find out, and yes, please do keep your eggs over the desk because if the eggs drop on the floor the raw egg, at least, is going to be a real mess to clean up!)
3. Make a list the ways you have found to tell all hard-boiled eggs from all raw eggs:
4. Would you like to change your original hypotheses? If so, now is your chance The marked egg is (circle one) Raw Hard-boiled Why do you think this?
5. Now, how are you going to prove it? That's right, but you only get one chance. Go up to your teacher and break your egg over the bowl, and, if you are right, you'll get salt and/or pepper and be able to eat it. If not, you get to clean up the mess, so be careful!

Activity: Observation practice: Demonstrating the collapsing can

This experiment is the old stand-by, collapsing can. In this version, I use it to teach how to write a complete observation, and one set of procedures for scientific problem-solving.

Duration: 2 hours

Materials:

- empty, undented soda can
- bowl of cold
- method of heating
- dark colored background (i.e. cardboard)

Procedures:

1. Before I begin, I tell the students the names of tools I am using and also that the bowl contains cold water.
2. I direct them to watch the demonstration carefully, and then write down everything they observed. They must try to remember everything.
3. I then proceed to do the demonstration in silence, modeling listening for the sounds of boiling water. I put up a dark colored background so that they can see the presence of steam when the water boils.
4. I make a show of emptying the soda can of water, then putting back in only one tablespoon of water. They watch me light the burner, placing the can over the burner, and wait for the water in the soda can to boil. I then take the can carefully with tongs, and invert it into the bowl of cold water. The can's collapse is dramatic and instantaneous!

Observations:

After they write what they have observed, I ask them to voice the one big question they have!

Using Scientific Procedures:

1. What is the QUESTION you have now?
2. What is your guess or HYPOTHESIS about why the can collapsed? (I solicit several guesses, then select one to work with for part 3. If there is time, we may do more than one. Students suggest many things, and help each other explain.)
3. Let's TEST your hypothesis: Describe how we would test your idea to see if it is right or not. (Together, the students and I design a test. Usually the hypotheses

involve temperature changes, weakness of aluminum cans, and other suggestions which can be tested by varying where the hot water is, if the can is inverted or not, or whether or not the can needs to have boiling water in it to collapse. Then we try out their ideas. They are told to use complete sentences in all reporting, and to include drawings.)

Conclusion: What happened in your test? Were you right? What if you were not right -- how would you change your hypothesis? Write another explanation for why the can collapsed. (Answer all the questions, please!)

Activity: Observation skills practice: Unknown powders

In this experiment we will see if you are able to observe 3 powders very carefully.

Materials:

- piece of aluminum foil
- ruler
- scissors
- medicine dropper
- wooden stirring rod
- small container of water.
- sugar (unlabeled to all but the teacher)
- Plaster of Paris (unlabeled to all but the teacher)
- baking powder (unlabeled to all but the teacher)

Procedure:

1. Cut out 3 squares of aluminum foil. Make them 5 cm on each side.
2. Bend the edges of the foil to make a shallow dish. Make 3 of them. Label them A, B, & C.
3. Get a level spoonful of powder A. Put it in dish A. Add 15 drops of water. Stir it.
4. Observe carefully. Write your observations.
5. Get a level spoonful of powder B. Put it in dish B. Add 15 drops of water. Stir it.
6. Observe carefully. Write your observations.
7. Get a level spoonful of powder C. But it in dish C. Add 15 drops of water. Stir it.
8. Observe carefully. Write your observations.
9. One powder was sugar. How could you tell which one it was?
10. One powder was Plaster Of Paris. Which one?
11. One powder was Baking Powder. It made bubbles. Which one was it?

Activity: Observing a candle

Observation practice is one of the most important activities in a science classroom. Here is one that gives the students practice, while dealing with an ordinary, but often ignored, daily object.

MATERIALS:

- candles
- matches
- plastic stand (or some other type of holder)You can copy these questions directly onto a student worksheet

Procedure:

MOST PEOPLE HAVE USED CANDLES. VERY FEW PEOPLE HAVE TAKEN THE TIME TO OBSERVE A CANDLE CAREFULLY. THAT IS WHAT YOU WILL DO NOW. ANSWER QUESTIONS 1-8 BEFORE YOU LIGHT YOUR CANDLE.

1. Draw the candle.
2. What is the color of the string at the top of the candle?
3. Describe what the candle feels like.
4. Can you see any marks, or spots, inside the candle?
5. Look at the bottom of the candle. Is the string the same color as at the top?
6. Describe how hard the candle is. Tell if it is hard in some places, and soft in others.
7. Say something about the candle.

LIGHT YOUR CANDLE. TAKE IT TO YOUR DESK. STAND IT UP ON YOUR PLASTIC SQUARE. BE CAREFUL!
ANSWER THESE QUESTIONS AFTER YOU LIGHT YOUR CANDLE.

1. How much of the exposed string (1/2, 1/3, etc.) is surrounded with flame?
2. What colors are in the flame?
3. The greatest part of the flame is what color?
4. Draw the flame. Be sure to show the string.
5. Is there any smoke?
6. What must you do to make smoke?
7. What color is the smoke?
8. Where is the flame dark?
9. Does the flame come to a sharp point?
10. What can you do to change the shape of the flame?
11. Draw a line to show how far into the candle the light goes.
12. Does the top of the candle have a little cup of melted wax?
13. Is the cup the same on all sides?

14. Is wax dripping down the side of the candle?
15. Draw the wax that is dripping down the side of the candle.
16. Let ONE DROP of melted wax fall onto your hand. How hot is it?
17. For how long a time does the drop of melted wax stay hot?
18. Does the candle make any noise as it burns?
19. Can you read the page by the light of your candle?
20. Does the burning candle produce an odor?

Resources

http://www.biology4kids.com/files/studies_scimethod.html

http://teacher.pas.rochester.edu/phy_labs/appendixe/appendixe.html

http://www.sciencebuddies.com/mentoring/project_scientific_method.shtml

http://en.wikipedia.org/wiki/Scientific_method

http://www.experiment-resources.com/history-of-the-scientific-method.html